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BIOMETRICAL AND ECONOMIC ANALYSES OF COW AND CALF VARIABLES AS RELATED TO PREWEANING AND POSTWEANING PERFORMANCE OF CALF

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Biometrical and economic analyses of cow and calf variables as related to preweaning and postweaning performance of calf" submitted by Herbert Bruce Jeffrey, B.Sc. (Ag.), M.Sc. in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

A study was conducted to determine the joint and separate influences of several cow-calf variables on preweaning and postweaning performance of the calf. Variables considered were: breed, age, body weight, body measurements, summer and winter weight changes and milk yield of dam; breed of sire; and birth weight, weaning age and sex of calf. The study involved 4 years of data (1966-1970) from the University of Alberta beef breeding herd. The breeding composition of the herd was complex. The data were analyzed by stepwise-multiple regression procedure using a general linear model.

Using oxytocin to stimulate milk ejection, milk yield and percentage milk components were determined for 176 and 201 cows for 1966 and 1967 respectively. The 1966 and 1967 data were analyzed separately for each year to determine the interrelationships of milk components, the best suited milk component or combination of milk components for predicting preweaning performance of calf, factors affecting milk yield and the effect of cow-calf variables on preweaning performance of calf. Influence of cow-calf variables on calf performance to 365 days of age were studied using 3 sets of data (1966-67, N = 176; 1967-68, N = 167; 1968-70, N = 285). Cow weights and body measurements were determined for 173 cows in October, 1969. The influence of cow size variables on preweaning and postweaning performance of calf was studied.

Milk yield alone was found to be a suitable parameter for predicting preweaning performance.

Only 40 to 52% of the total variance in milk yield was explained.

Breed and age differences accounted for 82 to 87% of explained variance in milk yield. Holding cow age constant, cow weight accounted for 0.0 to 8.0% of the variance in milk yield. Summer weight gain of cow was negatively associated with milk yield. Winter weight loss of dam, sex and birth weight of calf had little influence on milk yield.

Milk yield accounted for about 60% of the variation in average daily gain (ADG) of calf to weaning. A 1 kg increase in daily milk yield resulted in 11 to 14 kg increase in weaning weight. Breed of dam accounted for about 23% of the variance in ADG to weaning, most of which was accounted for by breed differences in milk yield. Breed of sire accounted for 1.4 to 5.7% of the variance in ADG to weaning. Breed of sire and dam differences together explained 0.2 to 13.8% of the variance in postweaning average daily gain. A 1 kg increase in birth weight resulted in a 2.86 to 4.27 kg increase in calf weight at 1 year of age. A 10 kg increase in postcalving weight of dam resulted in about a 0.7 kg increase in weaning weight of calf.

A 10 kg increase in postcalving weight of dam for 3 sets of data resulted in a -0.24, 1.96 and 2.12 kg increase in calf weight at 365 days of age. Height and weight of cow together were found to be more consistent in predicting calf performance than either variable alone.

Using current feed costs and cattle prices, a marginal analysis indicated that larger cows would be less profitable than smaller cows when calves were sold at 180 days of age but more profitable when calves were sold at 365 days of age where calves were fed a predominantly concentrate ration ad libitum over the postweaning period. Additional weaning weight realized through increased milk yield was found to be highly profitable.

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GENERAL INTRODUCTION

Economic pressures of a complex competitive society demand that profit maximization be a major objective of any beef breeding system. However, to realize this goal, it is necessary to understand the effects and interrelationships of a multitude of traits, to identify those traits of major economic importance and to establish priorities accordingly. As evidenced over the past ten years by the wide acceptance of performance and progeny testing, artificial insemination and use of diverse genetic material, rapid rate of growth has become a criteria of major importance not only for selecting breeding animals but for comparing breeding systems. Such comparisons, although extremely valuable, unfortunately seldom take into consideration the additional input required for additional output and hence do not reflect differences in net return. On preliminary examination, the economic advantage of rapidly growing cattle appears obvious. Heavier calves at weaning may be placed directly into feedlot. Cattle with a rapid rate of growth will reach slaughter weight at an earlier age, thus reducing maintenance requirement for feed, capital overhead and labor costs. However, increased growth rate of calf is frequently associated with higher milk yielding dams of larger mature size, particularly when breeds excelling in these traits are incorporated with the traditional beef breeds. Costs for cow maintenance and milk production have to be absorbed by the calf marketed.

Since milk yield of dam is known to be highly associated with growth rate of calf to weaning (Drewery et al., 1959, Gleddie and Berg, 1968; Neville, 1962), the first objective of this study was to determine the milk variable or combination of milk variables that was

best suited for predicting growth rate of calf. A second objective of the study was to determine the effect of several factors, including breed, age, body weight, and body weight loss of cow on milk yield. Quantifying those traits that influence milk yield could have important implications in respect to a beef breeding program. A third major objective of the study was to determine the joint and separate effects of several cow-calf variables on preweaning performance. Milk yield and body weight of dam were of particular interest since both variables directly influence the feed requirement of the cow and hence are necessary for establishing input-output relationships. Factors influencing postweaning performance and weight at 365 days of age were also examined. Again, cow size was of particular interest. If calves from larger cows continue to grow more rapidly during the postweaning period, the net efficiencies of such gain could be credited back to the larger cow.

In respect to determining the influence of cow size on growth rate of progeny, there is some question as to how well body weight reflects physiological cow size since weight varies with body condition. A study was conducted to determine the joint and separate effects of cow-body weight and measurement variables on performance of progeny.

Finally, a marginal economic analysis in respect to the association of calf performance with cow size and milk yield was undertaken.

I. Evaluation of milk variables as measures of milk effect on preweaning performance

A. INTRODUCTION

The influence of milk yield on preweaning performance in beef cattle has been well established. However, in relating milk yield to future studies of preweaning performance, it is important to know which milk variable or combination of milk variables is best suited for explaining variance or for predicting calf response.

The objective of this study was to determine the separate and joint effects on beef cattle preweaning performance of milk yield, total energy, total protein, total solids and percentages of butterfat, protein and solids-not-fat. Single and repeated milkings were examined with the objective of predicting preweaning performance.

B. EXPERIMENTAL

The data were obtained during 1966 and 1967 from the University of Alberta beef breeding herd. Included in the analysis were 176 cows for 1966 and 201 cows for 1967, respectively averaging 5.1 and 4.3 years of age. The calves were weaned on approximately October 14 of both years averaging 170 and 179 days of age respectively for 1966 and 1967. The breeding of the cow herd consisted of Hereford, Angus, Galloway, Hybrid and Hereford-Hybrid crosses. The Hybrids were a synthetic of Angus, Galloway and Charolais breeding (Berg and McElroy, 1968). Breed of sires for 1966 calves were Hereford, Charolais, Hybrid and Brown Swiss and for 1967 calves, Hereford, Hybrid and Shorthorn. Therefore, breed combinations were complex and for purposes

of this study, calculations were carried out across the herd for each year with no attempt to specifically separate breed differences. Specific breed effects will be a subject for later discussion. Preliminary analyses indicated breed differences of percentage milk components to be small and in most instances not significant, $P < .05$.

The management and nutrition of the herd were reported by Berg and McElroy (1968). Summer pasture conditions were similar for both years until August, when 12.45 cm of rain fell in 1966 compared to 2.75 cm in 1967.

In both years, the cow herd was milked in August and again in October. At the same time, calf weights were recorded. Milking procedures were as reported by Berg and Peschiera (1967). The cows were injected with 20 I.U. of oxytocin to stimulate milk ejection. The milk was removed by teat tubes and yields were measured over a 6-hour period. The 6-hour milk yield was multiplied by 4 to estimate 24-hour yield. Samples were analyzed for butterfat, protein and solids-not-fat. Total energy, total protein and total solids were calculated. Total energy was calculated using the formula, Energy (Kcal/lb milk) = 41.84 (% fat) + 22.29 (% SNF) - 25.58, (Tyrell and Reid, 1965). The data were analyzed by stepwise multiple regression technique (Cohen, 1968; Draper and Smith, 1966; Johnston, 1963) using the least squares linear model: $Y_i = B_o + B_k X_{ki} + e_i$, where Y_i = the ith dependent variable, B_o = the Y intercept, B_k = the regression coefficient, X_k = the kth independent variable of $X_1, X_2, \ldots, X_k$ and e_i = a random disturbance term of Y_i.

The dependent variables were average daily gain (ADG) of calf for three periods; birth to August, August to October (weaning) and birth

to October for 1966 and 1967. The independent variables were 24-hour yield of milk, protein (Prot), energy (En) and total solids (TS) and percentages of butterfat (BF%), solids-not-fat (SNF%) and protein (Prot%). The independent variables were calculated for August, October, and the average of August and October for 1966 and 1967. The averages of milk component percentages for the two periods were weighted in accordance with the formula:

$$\frac{\text{August (Comp\% x Milk Yield)} + \text{October (Comp\% x Milk Yield)}}{\text{August Milk Yield} + \text{October Milk Yield}}$$

where Comp % = either BF%, SNF% or Prot%.

C. RESULTS AND DISCUSSION

Mean ADG, milk yield and milk components

Means and standard deviations of milk variables are shown in Table 1. Comparing the two years under study, as a reflection of the better grazing season, cows produced more milk in 1966 (5.62 vs. 4.64 kg/24-hr. average for August and October milking) and their calves had a higher ADG to weaning (0.87 vs. 0.78 kg). Percent BF for the August milking was 4.66 for 1966 and 4.10 for 1967. Respectively for August 1966 and 1967, Prot% was 3.93 and 3.28 and SNF% was 8.94 and 8.67. Gleddie and Berg (1968) reported percent milk components for August milking of beef cows to be 3.9% BF, 3.5% Prot and 9.1% solids-not-fat. Melton et al. (1967), with Hereford, Angus and Charolais cows, reported average BF% as 2.79 and SNF% as 8.81. They indicated their findings for BF% as being low compared to other reports in the literature and cited Dawson et al. (1960) as reporting 3.98% BF for milk

from beef Shorthorn cows. Schwulst et al. (1966) working with three groups of Angus cows reported BF% from 3.94 to 4.34, Prot% from 2.97 to 3.03 and SNF% from 8.49 to 8.65.

Mean milk component percentages were somewhat higher for 1966 with the exception of BF% for the October milking which was higher in 1967. Laben (1963) concluded, from a literature review, that underfeeding will reduce SNF% and percent protein. Percent BF and SNF% tended to increase towards the termination of lactation. Laben (1963) reported a study with Holsteins where SNF% was lowest during the second month of lactation, gradually increased to the eighth month and rose sharply in the ninth and tenth months. Change from August to October in Prot% was considerably less than change in either BF% or SNF percent. Towards the end of lactation Prot% declined slightly in 1966 but increased in 1967.

Intercorrelations of milk yield, En, Prot and TS

The phenotypic intercorrelations among milk yield, En, Prot and TS were all high and positive, ranging from 0.85 to 0.99 (Table 2). Energy as calculated and TS were almost perfectly correlated (r = 0.99). The correlations of milk yield with TS and En respectively were 0.97 and 0.94. The correlations of Prot with milk yield, En and TS were slightly more variable ranging from 0.85 to 0.95.

Correlations reported in the literature were: for milk yield with total BF, SNF and Prot respectively as 0.90, 0.99 and 0.93 (Batra et al., 1969); for milk yield with BF, SNF and TS, respectively as 0.88, 0.98 and 0.97 (Blanchard et al., 1966); and for En and TS as 0.98, En and Prot 0.81 and TS and Prot 0.88 (Black and Voris, 1934). These results

TABLE 1: Means and standard deviations for milk variables from 24-hr.-milk yield for 1966 (N = 176) and 1967 (N = 201) data

	1966				1967			
	August		October		August		October	
Variables[1]	Mean	S D	Mean	S D	Mean	S D	Mean	S D
Milk....kg	6.11	1.75	5.13	1.86	5.48	1.55	3.80	1.28
Prot....kg	0.24	0.07	0.20	0.07	0.18	0.05	0.13	0.04
En....Mcal	4.95	1.43	4.63	1.66	4.10	1.24	3.49	1.15
TS......kg	0.83	0.24	0.76	0.27	0.70	0.21	0.56	0.18
BF%......%	4.66	0.78	5.43	1.14	4.10	0.85	5.77	1.07
Prot%....%	3.93	0.51	3.53	0.54	3.28	0.32	3.51	0.49
SNF%.....%	8.94	0.53	9.50	0.38	8.67	0.44	9.18	0.46

1 See text for abbreviations.

are in general agreement with other workers (Basco, 1969; Johnson, 1957; Tyler and Hyatt, 1947).

The above studies involve a wide array of cattle breeds and conditions, however, a high degree of consistency appears to exist among the reported inter-relationships of milk components. Christensen (1968) concluded that 90% of the response obtainable by direct selection for fat and protein yield could be obtained indirectly by selecting for milk yield alone. Because of the high genetic correlation among milk variables, Blanchard et al. (1966) concluded, "when selection is for milk only, the expected change in yield of SNF and total solids is nearly as great as if either SNF or total solids were the only trait for which selection was practiced".

Intercorrelations of milk yield and percent milk components

The phenotypic correlations of percent milk components and milk yield were low and predominantly negative. Correlations of milk yield with BF% ranged from 0.01 to -0.25, with Prot% from -0.05 to -0.24 and with SNF% from 0.02 to -0.36 (Table 2). These results are in general agreement with the literature. Robertson et al. (1956) as cited by Gleddie and Berg (1968) reported correlations of milk yield with BF%, Prot% and SNF% respectively as -0.03 to -0.14, -0.03 to -0.26 and -0.10 to -0.18. Johnson (1957), respectively for Holsteins and Jerseys, reported negative correlations between milk yield and BF% as -0.063 and -0.289, milk yield and SNF% as -0.081 and -0.106, and milk yield and TS% as -0.139 and -0.169. These results are in general agreement with others (Basco, 1969; Batra et al., 1969; Black and Voris, 1934; Blanchard et al., 1966; Tyler and Hyatt, 1947). Gleddie

and Berg (1968), with beef breeds, reported BF% being positively correlated with milk yield and negatively correlated with Prot% and SNF percent. Melton et al. (1967), using Hereford, Angus and Charolais cows, reported a positive correlation of 0.20 between milk yield and BF% and a negative correlation between milk yield and SNF%.

The intercorrelations among percent milk components were all positive (Table 2). These ranged from 0.09 to 0.18 for Prot% and BF%, 0.16 to 0.55 for Prot% and SNF% and 0.12 to 0.49 for BF% and SNF percent. Gleddie and Berg (1968) reported the intercorrelations between BF%, Prot% and SNF% as ranging between 0.33 to 0.59. Melton et al. (1967) reported a positive correlation between BF% and SNF% ($r = 0.26$). Blanchard et al. (1966) concluded, "selection for percentage traits would tend to decrease milk yield but have little effect on yield of SNF and total solids". Similar conclusions were reached by Thompson and Loganathan (1968).

Correlations of milk and milk components with ADG

As would be expected from the high intercorrelations, the correlations of milk yield, Prot, En and TS with ADG were relatively similar (Tables 2 and 3). The correlations of August milk yield, En and TS with ADG of calf from birth to August ranged from 0.75 to 0.77 in 1966 and from 0.69 to 0.70 in 1967. The correlations of Prot with ADG for the same periods were 0.69 and 0.62. The correlations of October milk yield, En and TS with ADG of calf from August to October were, respectively 0.43, 0.39 and 0.40 for 1966 and 0.47, 0.45 and 0.47 for 1967. Compared to milk yield, En and TS, the correlations of Prot with ADG were generally lower. One exception was the correlation between

October, 1967 Prot and ADG of calf from August to October (r = 0.53). Melton et al. (1967) reported a correlation of 0.58 between average daily milk yield and ADG at 77 days after parturition. These workers indicated as calves became older the correlations between milk yield and ADG tended to decline and were not significant. Gleddie and Berg (1968) reported correlations between ADG and milk yield, respectively. for June, July, August and October as 0.62, 0.75, 0.56 and 0.51. They reported a correlation of 0.84 between ADG from birth to weaning and average milk yield measured 4 times in the lactation.

As shown in Table 3, the correlation of milk yield and ADG from birth to weaning was consistent between years, 0.76 and 0.78. However the correlation between milk yield and weaning weight was 0.50 for 1966 and 0.68 for 1967, significant, $P < .05$. This inconsistency reflects ancillary influences on weaning weight, particularly calf age, birth weight and environmental differences between years. These effects will be considered later. Wilson et al. (1969) working with Angus-Holstein crossbreds obtained correlations for total calf gains of 0.46, 0.49 and 0.49 respectively with milk yield, solids corrected milk yield and energy. They concluded that measurements of milk composition may not be necessary in measuring the effect of milk yield of cows on growth rate of progeny.

As indicated in Tables 2 and 3 correlations of ADG with percentage milk components were low and in most instances nonsignificant. This is in general agreement with the literature (Gleddie and Berg, 1968; Melton et al., 1967; Wilson et al., 1969).

Table 2: Phentotypic correlations of milk yield, milk components and average daily gain of calf; 1966 data coefficients above diagonal (N = 176) and 1967 data coefficients below diagonal (N = 201)

Month and variable[1]	Milk	Prot	En	TS	BF%	Prot%	SNF%	Calf ADG (Aug.)	Calf ADG (Aug.-Oct.)	Calf ADG (Oct.)
AUGUST										
Milk		.90	.94	.97	-.16	-.11	.02	.75	.53	.79
Prot	.95		.87	.89	-.11	.30	.09	.69	.47	.71
En	.94	.91		.99	.14	-.07	.17	.76	.50	.78
TS	.97	.93	.99		.05	-.07	.17	.77	.51	.79
BF%	.01	.03	.32	.23		.09	.12	.02	-.04	-.01
Prot%	-.20	.09	-.13	-.13	.18		.16	-.08	-.04	.09
SNF%	-.07	.07	.10	.10	.29	.44		.09	-.03	.08
ADG (Aug.)	.69	.62	.70	.69	.19	-.19	-.17		.48	.96
ADG (Aug.-Oct.)	.41	.37	.35	.37	-.08	-.06	-.06	.38		.68
ADG (Oct.)	.71	.65	.70	.70	.13	-.18	-.15	.95	.64	
OCTOBER										
Milk		.94	.94	.97	-.21	-.05	-.36		.43	.66
Prot	.90		.89	.92	-.16	.28	-.25		.38	.64
En	.94	.85		.99	.12	.00	-.17		.39	.62
TS	.97	.88	.99		-.02	-.01	-.20		.40	.64
BF%	-.25	-.23	.06	-.03		.13	.43		-.10	-.12
Prot%	-.24	.19	-.19	-.19	.12		.26		-.09	.00
SNF%	-.17	.04	.02	-.01	.49	.55			-.14	-.19
ADG (Aug-Oct.)	.47	.53	.45	.47	-.13	.10	.06			
ADG (Oct.)	.76	.75	.76	.77	-.07	-.04	.01			

[1] See text for abbreviations.

1966 data
r = 0.14 significant at $P < .05$.
r = 0.18 significant at $P < .01$.

1967 data
r = 0.15 significant at $P < .05$.
r = 0.19 significant at $P < .01$.

TABLE 3: Phenotypic correlations of milk yield and milk components averaged over August and October milkings and average daily gain of calf from birth to October; 1966 data coefficients above diagonal (N = 176) and 1967 data coefficients below diagonal (N = 201)

Year and variable[1]	Milk	Prot	En	TS	BF%	Prot%	SNF%	Calf ADG (Oct.)	Weaning weight
Milk		.94	.95	.97	-.22	-.13	-.15	.78	.50
Prot	.95		.92	.94	-.16	.19	-.04	.76	.49
En	.96	.91		.99	.07	-.06	.006	.76	.48
TS	.98	.94	.99		-.02	-.07	-.01	.78	.50
BF%	-.06	-.05	.22	.14		.19	.34	-.07	-.10
Prot%	-.20	.11	-.15	-.15	.06		.33	-.06	-.04
SNF%	-.10	.07	.05	.03	.36	.59		-.02	-.01
ADG (Oct.)	.76	.73	.76	.77	.08	-.14	-.09		.81
Weaning Weight	.68	.67	.70	.70	.09	-.09	-.01	.90	

[1] See text for abbreviations.

1966 data
$r = 0.14$ significant at $P < .05$.
$r = 0.18$ significant at $P < .01$.

1967 data
$r = 0.15$ significant at $P < .05$.
$r = 0.19$ significant at $P < .01$.

Multiple association between ADG and milk yield, milk components and percent milk components

The percentage of total variance explained, residual variances, partial regression coefficients and standard errors for ADG of calf by regression of selected milk variables are given in 3 equations repeated for the periods under study. These results are shown in Table 4 for August milking and ADG of calf from birth to August for 1966 and 1967; and in Table 5 for October milking and ADG of calf from August to October.

In 1966, for both periods, milk yield alone explained almost as much total variance as milk yield and milk components combined (Equation 2a, Tables 4 and 5). Percent BF, SNF% and Prot% together explained only 1.7 and 2.5% of the total variance in ADG respectively for August and October milking (Equation 3a, Tables 4 and 5). The 1966 results are in agreement with Gleddie and Berg (1968), who reported that TS% accounted for an additional 2.7% of the variance in ADG of calf over milk yield alone and the inclusion of Prot%, SNF% and BF% accounted for only an additional 0.5 percent. However, in 1967 when milk yield of the herd was considerably lower, BF%, SNF% and Prot% combined, respectively explained 11.4% and 3.9% of total variance in ADG of calf for the two periods (Equation 3b, Tables 4 and 5). Percent milk components explained an additional 7% and 5% of total variance over milk yield alone, respectively for August and October, 1967, milkings (Equation 2b, Tables 4 and 5).

As would be expected, additional variance over milk yield explained by BF%, SNF% and Prot% was about equal to that explained by yield of protein, energy and total solids. However, with multiple regression

TABLE 4: Percentage of total variance explained, residual variance and partial regression coefficients (b) of regression of ADG from birth to August on several measurements of milk and milk components for 1966 (N = 176) and 1967 (N = 201) data

Equation	August milk variables entered sequentially into regression	% Total variance explained (R^2 x 100)	% Additional variance explained	Residual variance	b
1 (a) 1966	None			.0204	
	(f) Milk....kg	57.0		.0088	.0284*
	En....Mcal	59.0	2.1	.0085	.0431**
	Prot....kg	59.0	0.0	ϕ	
	TS......kg	59.0	0.0		
1 (b) 1967	None			.0232	
	(f) Milk....kg	47.5		.0122	.1576**
	En....Mcal	49.6	2.1	.0118	.4723**
	TS......kg	54.5	4.9	.0107	-.3488**
	Prot....kg	54.5	0.0	ϕ	
2 (a) 1966	(f) Milk....kg	57.0		.0088	.0634**
	BF.......%	59.2	2.2	.0084	.0265**
	SNF......%	59.4	0.3	.0084	.0142
	Prot.....%	59.4	0.0	ϕ	
2 (b) 1967	(f) Milk....kg	47.5		.0122	.0660**
	BF.......%	51.0	3.5	.0115	.0435**
	SNF......%	54.5	3.5	.0107	.0684**
	Prot.....%	54.5	0.0	ϕ	
3 (a) 1966	(f) SNF......%	0.8		.0204	.0148
	(f) Prot.....%	1.7	0.9	.0203	-.0035
	(f) BF.......%	1.7	0.0	.0204	.0267**
	Milk....kg	59.5	57.7	.0085	.0633**
	Prot....kg	59.5	0.0	ϕ	
	En....Mcal	59.5	0.0	ϕ	
	TS......kg	59.5	0.0	ϕ	
3 (b) 1967	(f) BF.......%	3.8		.0224	-.0070
	(f) SNF......%	9.4	5.6	.0212	-.0885**
	(f) Prot.....%	11.4	2.0	.0208	.0839
	En....Mcal	54.7	43.3	.0107	.0948
	Prot....kg	55.0	0.2	.0107	-.1723
	Milk....kg	55.2	0.2	.0107	.0511
	TS......kg	55.2	0.0	ϕ	

(f) Variable forced to enter regression preceeding non-forced variables.
** Significantly different from zero P∠.01, * P∠.05.
ϕ Not calculated, critical value for proportion of sum of squares entering regression was set at 0.001.

TABLE 5: Percentage of total variance explained, residual variance and partial regression coefficients (b) of regression of ADG from August to October on several measurements of milk and milk components for 1966 (N = 176) and 1967 (N = 201) data

Equation	October milk variables entered sequentially into regression	% Total variance explained (R^2 x 100)	% Additional variance explained	Residual variance	b
1 (a) 1966	None			.0327	
	(f) Milk....kg	18.1		.0268	.0579**
	Prot....kg	18.5	0.4	.0269	-.0448
	En....Mcal	18.5	0.0	ø	
	TS......kg	18.5	0.0	ø	
1 (b) 1967	None			.0387	
	(f) Milk....kg	22.5		.0311	.0005
	Prot....kg	27.9	5.4	.0291	.2378**
	En....Mcal	27.9	0.0	ø	
	TS......kg	27.9	0.0	ø	
2 (a) 1966	(f) Milk....kg	18.1		.0269	.0422**
	Prot.....%	18.6	0.5	.0269	-.0267
	SNF......%	18.7	0.1	.0270	.0172
	BF.......%	18.7	0.0	ø	
2 (b) 1967	(f) Milk....kg	22.5		.0311	.0826**
	Prot.....%	27.4	5.0	.0293	.0940**
	BF.......%	27.4	0.0	ø	
	SNF......%	27.4	0.0	ø	
3 (a) 1966	(f) SNF......%	1.9		.0322	.1447
	(f) Prot.....%	2.3	0.3	.0323	-.0260
	(f) BF.......%	2.5	0.2	.0324	.0084
	Milk....kg	18.8	16.3	.0271	.2971
	TS......kg	19.2	0.4	.0272	-.4503
	En....Mcal	19.6	0.4	.0272	.4558
	Prot....kg	19.6	0.0		
3 (b) 1967	(f) BF.......%	1.7		.0395	-.0071
	(f) SNF......%	3.6	1.9	.0389	.0295
	(f) Prot.....%	3.9	0.2	.0390	-.0120
	Prot....kg	28.1	24.2	.0293	.2361**
	Milk....kg	28.1	0.0	ø	
	En....Mcal	28.1	0.0	ø	
	TS......kg	28.1	0.0	ø	

(f) Variable forced to enter regression preceeding non-forced variables.
** Significantly different from zero P ∠.01, * P ∠ .05.
ø Not calculated, critical value for proportion of sum of squares entering regression was set at 0.001.

there is an advantage in using milk yield and percent milk components rather than milk yield and yield of milk components, since the intercorrelations of the former are considerably lower. High correlations between independent variables frequently result in unduly high standard errors of the regression coefficients and significance tests can be misleading (Johnston, 1963). Equation 3b of Table 4 is probably an indication of this condition. Energy accounted for 43.3% of additional variance but the regression coefficient was insignificant, ($t = 1.47$). Similarly in Equation 3a, Table 5, milk yield contributed 16.3% of additional variance but had an insignificant regression coefficient ($t = 1.36$). When intercorrelations of the independent variables approach 1, the determinant of the correlation matrix approaches zero.

Milk yield and percent milk components for August, October and the average of the two milkings were compared in Table 6 to indicate which of the three measurements would be most suitable in explaining variance in ADG of calf from birth to weaning. In 1966, there was little difference between the August milking and the two period average, both explaining about 60% of the variance in ADG (Equation 1 vs. 3). The October, 1966, milking explained only 43% of the variance (Equation 2). This pattern reversed in 1967. The October and two period average each explained about 58% of the variance of ADG, whereas the August milking explained 50% (Equations 5, 6 and 4, respectively). It is of interest that the two period average was comparable between years (Equations 3 and 6). Gleddie and Berg (1968) reported the average of June, July, August and October milkings to account for 71% of the variance in calf ADG. They reported that the inclusion of individual monthly milk records to the equation added only 1.6% to

TABLE 6: Percentage of total variance explained, residual variance and partial regression coefficients (b) of regression of ADG from birth to weaning on milk yield and percent milk components for August and October milkings and average of the two milkings for 1966 (N = 176) and 1967 (N = 201) data

Equation		Independent variables entered sequentially into regression		% Total variance explained (R^2 x 100)	Additional variance explained	Residual variance	b
1.	1966	August	None			.0176	
			Milk....kg	61.7		.0068	.0610**
			BF.......%	63.3	1.6	.0066	.0208*
			SNF......%	63.5	0.2	.0065	.0125
			Prot.....%	63.5	ϕ		
2.	1966	October	Milk....kg	43.4		.0100	.0484**
			SNF......%	43.7	0.2	.0100	.0186
			BF.......%	43.7	ϕ		
			Prot.....%	43.7	ϕ		
3.	1966	Average	Milk....kg	60.5		.0070	.0640**
		August	SNF......%	61.5	1.0	.0069	.0279
		and	BF.......%	62.0	0.5	.0068	.0129
		October	Prot.....%	62.0	ϕ		
4.	1967	August	None			.0194	
			Milk....kg	50.4		.0097	.0626**
			BF.......%	51.8	1.4	.0094	.0268**
			SNF......%	53.9	2.1	.0091	-.0483**
			Prot.....%	53.9	ϕ		
5.	1967	October	Milk....kg	57.5		.0083	.0889**
			SNF......%	59.9	2.4	.0078	.0182
			Prot.....%	60.4	0.5	.0078	.0306
			BF.......%	61.0	0.6	.0077	.0118
6.	1967	Average	Milk....kg	58.0		.0082	.0792**
		August	BF.......%	59.5	1.5	.0079	.0296**
		and	SNF......%	59.8	0.3	.0079	-.0415
		October	Prot.....%	60.1	0.3	.0079	.0330

** Significantly different from zero P ∠ .01, * P ∠ .05.

ϕ Not calculated, critical value for proportion of sum of squares entering regression was set at 0.001.

explained variance in ADG above average milk yield alone. Averaging of milk yield records would appear to give as satisfactory results as considering individual records in combination.

As indicated above, percent milk components for August and October milking respectively explained an additional 7% and 5% of variance in ADG to August and ADG from August to October for 1967. However, percent milk components for the two-period average in 1967, only explained an additional 2.1% of variance in ADG from birth to weaning (Equation 6, Table 6). Therefore the addition of milk components over milk yield alone had very limited value as predictors of preweaning growth rate.

The quadratic effect of milk yield on ADG

The response of ADG of calf to milk yield was essentially linear. The quadratic effect of milk yield for the average of August and October milkings on ADG of calf from August to October explained only an additional 0.4% and 0.6% variance over the linear effect of milk yield, respectively for 1966 and 1967. For ADG of calf from birth to October, the quadratic effect of milk yield explained an additional 1.7% and 0.3% variance, respectively for 1966 and 1967. The regression coefficient of the quadratic effect for October, 1966 ADG differed significantly from zero ($P < .01$). None of the other regression coefficients for quadratic effect were significant. This suggests that the higher milk yield in 1966 resulted in a tendency for ADG of calf to increase at a decreasing rate with additional units of milk intake. If beef cattle are bred for higher milk production, the measurement of the curvilinear response of ADG on milk yield will

probably become more important.

It can be concluded from the present study that milk yield alone is as good as any other single milk variable as a measurement of associated response of calf growth rate. The average of two milkings was more reliable than a single milking. The inclusion of milk component percentages added very little to explained variance above milk yield alone for ADG from birth to weaning, however the inclusion of percent milk component may be of value in some instances. The response of ADG to milk yield was essentially linear in this study.

II. Factors influencing milk yield

A. INTRODUCTION

The influence of milk yield of dam on preweaning performance of progeny has been well established and accounts for about 60% of the variation in average daily gain to weaning (Chapter 1). Where attainment of high weaning weights within a cow-calf enterprise has priority, adequate milk production becomes paramount. It is the purpose of this study to examine the effect of several cow-calf variables on milk yield including: breed, age, size and weight change of dam and weaning age, sex and birth weight of calf.

B. EXPERIMENTAL

The present investigation involved data from the University of Alberta beef breeding herd. Included in the analyses were 176 cows for 1966 and 201 cows for 1967 with average ages of 5.1 and 4.3 years, respectively. The management and nutrition of the herd were reported by Berg and McElroy (1968).

The breeding herd was separated into three groups for wintering: wet mature cows (those that had nursed calves the previous summer), yearlings and wet 2-year olds, and dry cows. From early January to late March the feeding schedule was as follows:

Hay - 32.7 kg per head per week to all cows and heifers - fed 3 times weekly (Monday, Wednesday and Friday).

Oats - wet cows, 2-year olds and yearlings, 12.3 kg per head per week - three equal offerings (Tuesday, Thursday and Saturday).

Straw - approximately 2.3 kg per head on oat days or Sundays when

weather was severe (i.e. below 0°F in the morning).

Pellets - a barley-soybean-meal pellet of 29% crude protein and containing 32,000 I.U. Vitamin A per kg was incorporated with the oats and fed to all cows and heifers at 0.9 kg per week.

During summer, pasture was provided with no additional supplement except for nursing 2-year-olds which were given 12.3 kg of oats per week for 4 weeks prior to the breeding season as a flushing ration.

Summer pasture conditions were similar for both years up until August. In 1966, 12.7 cm of rain fell in August compared with 2.8 cm for 1967, making 1966 a much better year for calf preweaning performance and associated variables.

In both years, the cow herd was milked in August and again in October. Milking procedures were reported by Berg and Peschiera (1967). Milk ejection was stimulated by injecting intravenously 20 international units of oxytocin. Milk yields were measured over a 6-hour period and multiplied by 4 to give an estimated 24-hour-milk yield.

An analysis of the milk data associated with this study was reported in Chapter 1. Milk yield alone was shown to be a suitable variable in accounting for variance of preweaning average daily gain (A.D.G.) as associated with milk. It was indicated that the average of two milkings was more consistent in explaining A.D.G. from birth to weaning than a single milking. For purposes of this study, the average daily milk yield for August and October milkings (milk yield) was used as a measurement for the milk yield variable.

Body weights of cows were recorded immediately postcalving and postweaning in October. Winter and summer weight changes of cows were

calculated, respectively from October to postcalving and from post-calving to October.

Breed of dam categories included: Hereford (HE), Angus and Galloway (AG), and hybrid (HY) for 1966 data. For 1967 data, breed of dam categories were similar to 1966 except for a group of first calf heifers which were crosses and reciprocal crosses of HE and hybrid breeding (HEHY). The hybrids were a synthetic of Aberdeen Angus, Galloway and Charolais breeding.

The data were analyzed by stepwise multiple regression using the general linear model $Y_i = B_o + B_1 X_{1i} + \ldots + B_k X_{ki} + e_i$ where Y_i = the ith dependent variable, B_o = the constant, B_k = the partial regression coefficient for the X_k independent variable and e_i = a disturbance term of Y_i.

The partial regression coefficient B_k is the regression of Y_i on X_k holding constant all other independent variables entered into the equation. For partitioning variance, percent added variance rather than the square of the partial correlation coefficient was used to provide a common base for purposes of comparison. Percent added variance is the ratio of added variance to total various multiplied by 100 whereas the square of the partial correlation coefficient is the ratio of added variance to residual variance. Percent additional variance explained by each independent variable must be considered in relation to its sequence of entry into the equation, where the effect of the preceding independent variables are statistically held constant. Thus, in the equation $Y = B_o + B_1X_1 + B_2X_2$, where X_1 enters the equation first, the variance of Y explained by X_2 is additional to the variance of Y explained by X_1. Where X_1 and X_2 are correlated, part

of the effect of X_2 may be removed with X_1. Therefore, the percent added variance explained by any independent variable is conditional to the preceding independent variables entered into the equation.

The combined effects of all independent variables on milk yield were examined by forcing cow age and cow-age squared into the equation first and allowing all other variables to enter the equation in order of the highest partial correlation coefficient with the dependent variable. The effect of age of dam on milk yield was found to be curvilinear, hence cow-age squared was included as an independent variable.

The independent effect of a particular independent variable on milk yield was examined by holding constant certain variables selected on a priori reasoning and forcing the variable of interest to enter the equation last.

C. RESULTS AND DISCUSSION

The means and standard deviations for cow and calf data for 1966 and 1967 are given in Table 7. Mean postcalving weights of cows for 1966 and 1967 were 411 and 405 kg, respectively. A considerable difference between years was apparent in respect to summer weight gain of cows, milk yield and calf performance. Compared with 1967, the cows in 1966 gained 25 kg more weight, averaged 0.98 kg more in milk yield and weaned calves 10 kg heavier, even though the calves were 8 days younger at weaning time. The between year differences in herd performance largely reflected difference in grazing conditions.

Combined effects

A partitioning of percent total variance of milk yield and

TABLE 7: Means and standard deviations of cow and calf data

Variable		1966 Mean	1966 S.D.	1967 Mean	1967 S.D.
Cow data					
Age	yrs	5.10	2.21	4.26	2.03
Postcalving weight	kg	411.00	68.19	404.86	63.45
Winter weight loss	kg	58.54	33.31	--	--
Summer weight gain	kg	73.46	30.42	47.55	33.28
August milk yield	kg	6.11	1.75	5.48	1.55
October milk yield	kg	5.13	1.86	3.80	1.28
Calf data					
Age	days	170.21	17.98	178.55	13.32
Birth weight	kg	35.57	5.18	33.76	3.67
Actual weaning weight	kg	184.13	27.71	173.73	25.65
A.D.G. to weaning	kg	0.87	0.18	0.77	0.20

partial regression coefficients of milk yield on several cow and calf variables are given in Table 8 for 1966 and 1967 data. Total variance of milk yield explained by all variables considered was only 40% for 1966 and 52% for 1967 (Equations 1 and 2). Breed and age differences of dam accounted for 33 and 45% of total variance of milk yield, respectively for 1966 and 1967 (Equations 1 and 2, Table 8). When cow age, cow-age squared and breed of dam were held constant the contribution of the remaining variables in explaining variance of milk yield were small, ranging from 0 to 2.9 percent. However, the regression coefficients for calf age at weaning, cow summer gain and calf sex were significantly different from zero. Since summer gain tends to nullify the effect of postcalving weight on milk yield, this variable was excluded in Equations 3 and 4, Table 8. As shown in Equation 4, postcalving weight accounted for 2.1% of additional variance in milk yield and the regression coefficient was significant ($P < .05$).

Simple and independent effects

Breed of dam

Differences in milk yield between breeds of dam were highly significant. The AG and HY groups were about equal in milk yield, excelling HE dams by 1.20 and 1.50 kg for 1966 and 1967, respectively.

As indicated in equations 1(a) and (b), Table 9, when age and age squared of dam and age and sex of calf were held constant, breed of dam differences accounted for an additional 17.9 and 32.8% of total variance in milk yield for 1966 and 1967, respectively. Including birth weight in the equation had little influence on the effect of breed of dam on milk yield (Equations 2(a) and (b) Table 9).

TABLE 8: Percent total variance (R^2 x 100), percent additional variance (A.V.) and partial regression coefficients (b) of average milk yield (kg) sequentially regressed on several cow-calf variables recorded in 1966 and 1967

			Independent variables								
Equation	Av. milk yield		Cow‡ age (yrs)	Cow‡ age squared	Breed of dam	Calf age (days)	Cow summer gain (kg)	Calf sex	Cow post calving weight (kg)	Calf birth weight (kg)	Cow winter weight loss (kg)
1.	1966										
	Order of entry⊕		1	2	3	4	5	6	7	8	9
	R^2 x 100	%	10.5	15.3	32.6	35.5	37.8	39.5	39.8	I	I
	A.V.	%	-	4.8	17.3	2.9	2.4	1.6	0.3	-	-
	b	kg	1.4375**	-0.1171**	-	-0.0174**	-0.0111**	0.4212*	-0.0022	-	-
2.	1967										
	Order of entry		1	2	3	5	4	6	7	8	-
	R^2 x 100	%	4.6	12.6	45.1	49.4	47.3	50.8	51.8	52.1	-
	A.V.	%	-	8.0	32.5	2.1	2.2	1.4	1.0	0.3	-
	b	kg	0.9576**	-0.0792**	-	-0.0154**	-0.0059*	-0.3562*	0.0029	0.0244	-
3.	1966										
	Order of entry		1	2	3	4	-	5	6	7	-
	R^2 x 100	%	10.5	15.3	32.6	35.5	-	36.4	36.4	36.5	-
	A.V.	%	-	4.8	17.3	2.9	-	0.9	0.1	0.1	-
	b	kg	1.3047**	-1.0387**	-	-0.0173**		0.2842	-0.0011	0.8782	-
4.	1967										
	Order of entry		1	2	3	5	-	6	4	7	-
	R^2 x 100	%	4.6	12.6	45.1	49.0	-	50.4	47.2	50.5	-
	A.V.	%	-	8.0	32.5	1.8	-	1.4	2.1	0.1	-
	b	kg	0.8541**	-0.7297**	-	-0.0146**	-	-0.3557*	0.0042*	0.0146	-

‡ Variables forced to enter regression preceding other variables.
⊕ Indicates order in which variables were entered into equation.
** Significantly different from zero, $P < .01$, * $P < .05$.
I Proportion of sum of squares for entering variable was less than the critical limit set at 0.001.

Cow age and body weight

Correlations between age of dam and milk yield were quite low (0.32 and 0.22) as they were also for age of dam and A.D.G. of calf (0.32 for both years). However, as indicated in Figures 1 and 2, milk yield tended to increase with increased age of dam over the first three lactations, and then levelled off with maturity. Average daily gain to weaning is also plotted in Figures 1 and 2 showing a strong relationship to milk yield. The influences of milk yield and other factors on preweaning performance of calf will be considered in detail in a subsequent chapter.

Swiger et al. (1962) found beef cows to reach peak production at 6 years of age as expressed by weaning weight of progeny. Minyard and Dinkel (1965) found weaning weights to be lowest from 2 to 3 year old dams with weaning weight increasing at a diminishing rate from 2 to 8 years. Most of the increase in weaning weight was realized by the time the cows were 6 years of age.

Simple correlations between P.C.W. (postcalving weight) and milk yield were 0.28 and 0.38 for 1966 and 1967, respectively. Part of the relationship between P.C.W. and milk yield is associated with cow age, the correlation between cow age and P.C.W. being 0.73 for 1966 and 0.76 for 1967 data.

As shown in Equations 3 (a and b) and 5 (a and b), Table 9, cow age and P.C.W. explained 15.3 and 21.1% of the variance in milk yield for 1966 and 1967, respectively. Holding cow age constant, P.C.W. explained an additional 0.0 to 8.5% of variance in milk yield for 1966 and 1967, respectively (Equations 3 (a) and (b), Table 9). Including weaning age and sex of calf as constant variables had little

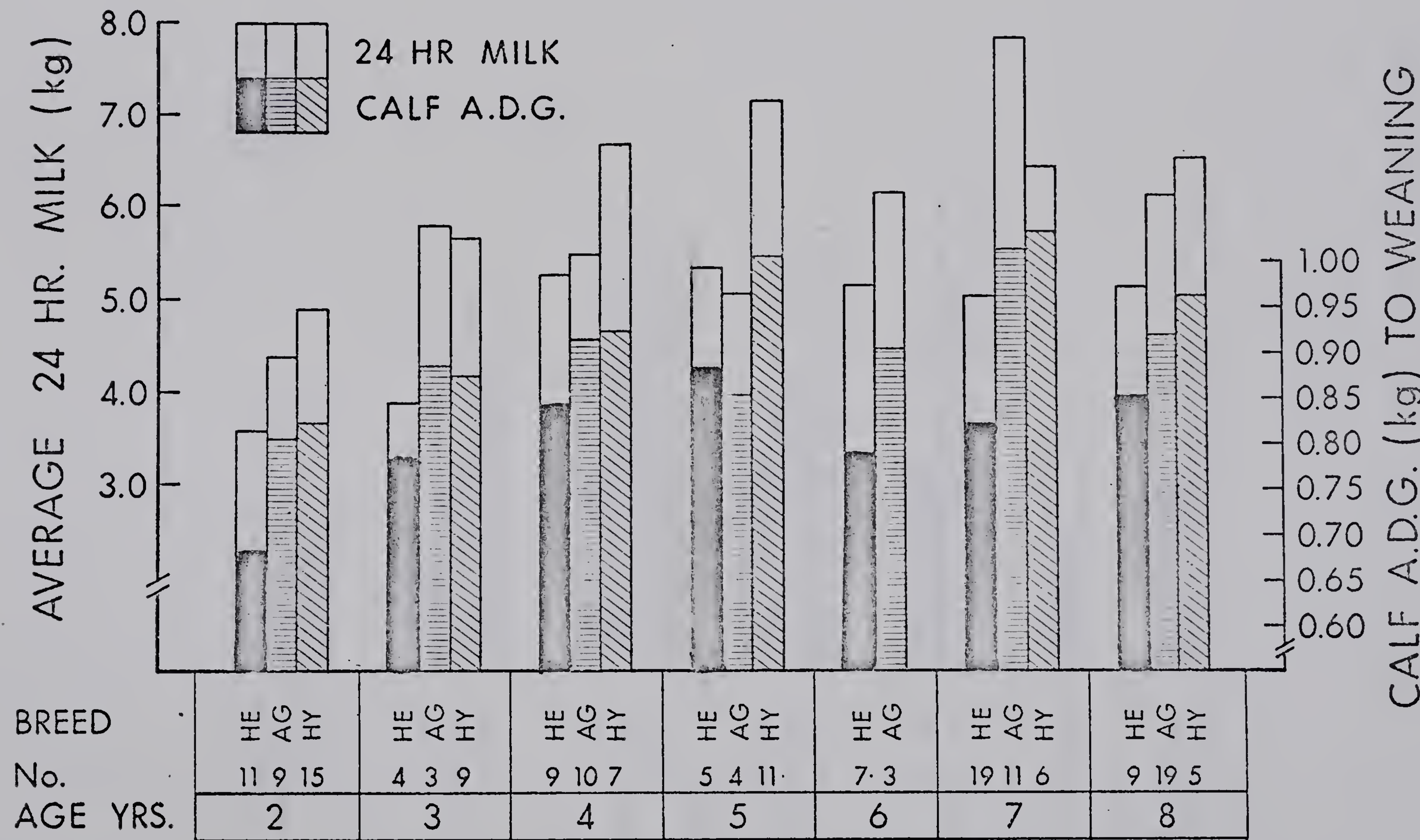

Figure 1. Milk yield and average daily gain to weaning by breed and age of dam 1966 data.

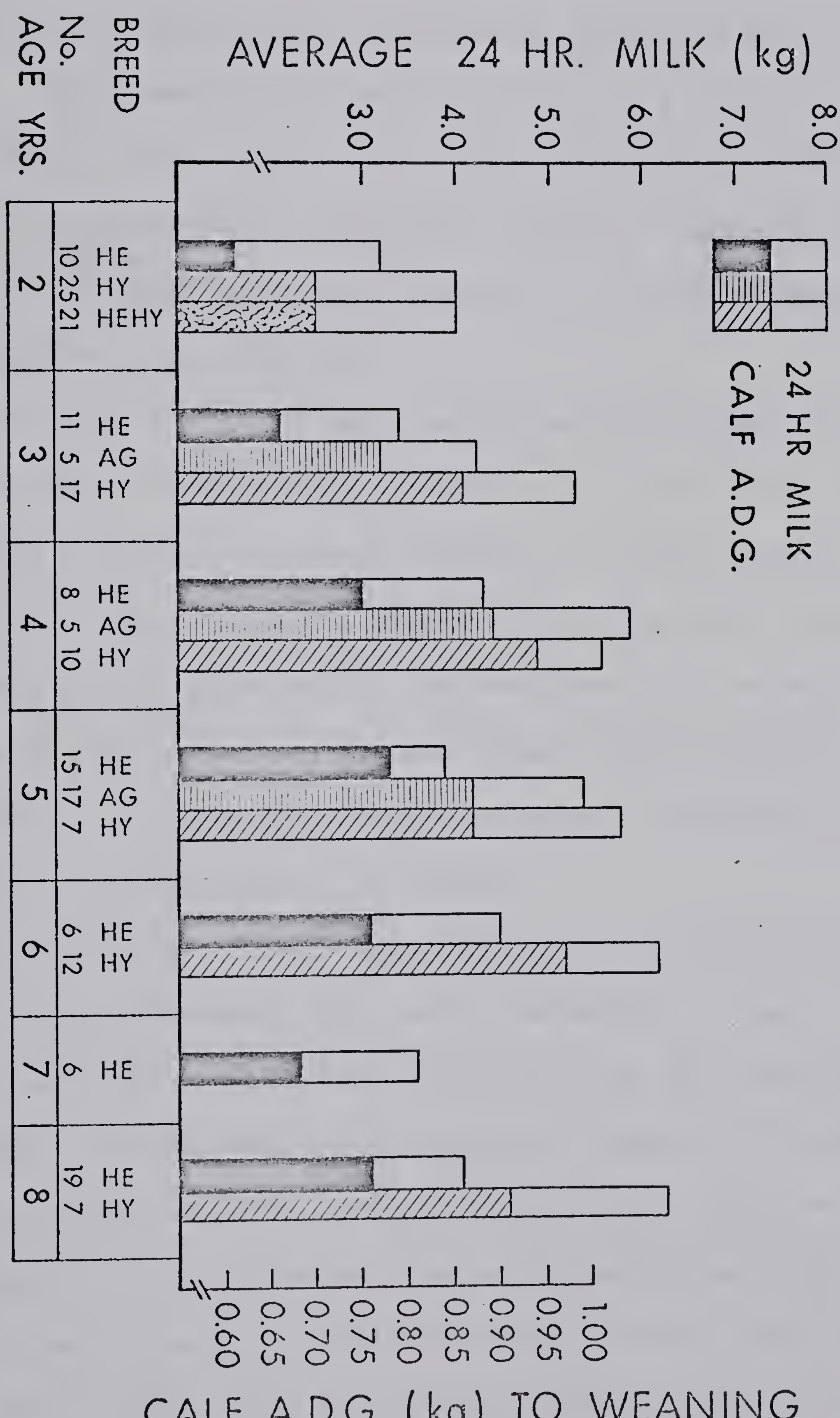

Figure 2. Milk yield and average daily gain to weaning by breed and age of dam 1967 data.

influence on P.C.W. in explaining variance in milk yield, (Equations 4(a) and (b), Table 9). Holding P.C.W. constant, cow age and cow-age squared together explained an additional 7.7 and 6.6% of variance in milk yield for 1966 and 1967, respectively (Equations 5(a) and (b), Table 9). After removing the effect of cow age, P.C.W. of cow had little effect on milk yield for 1966 data. However, for 1967, the regression coefficient was significant ($P < .01$), suggesting that an increase of 10 kg in P.C.W. would result in a 0.1 kg increase in milk yield (Equation 3(b), Table 9).

Clark and Touchberry (1962), working with Holsteins, reported a 400 lb increase in 180-day-milk production for each 100 lb increase in body weight with age of cow held constant. With body weight constant they reported that a one month increase in cow age was accompanied by an increase of 28.4 lb of milk. They concluded that as much or more variation in milk production was associated with body weight as with age. However, they reported a negative genetic correlation between body weight and milk yield ($r_g = -0.12$).

Davis and Morgan (1943) reported data from 4 dairy breeds where, with exception of Guernsey, body weight independent of age had considerably more influence on milk production than age independent of body weight. Holding body weight constant, Gaines et al. (1940) concluded cow age had little effect on milk yield. Mason et al. (1957) found little correlation between body weight and milk yield but reported a small positive correlation between wither height and milk yield. Other workers found very little phenotypic correlation between body weight and milk yield (Batra et al., 1969; Brun and Ludwig, 1969; Christian et al., 1965; Owen and Nielson, 1968). The inconsistency of

relationships between body size and milk yield, reported in the present study, indicates that selection for body size would give little assurance of any associated increase in milk yield.

Summer weight gain of cow

Cows with higher summer gain vs. lower summer gain tended to yield less milk. The simple correlations between summer gain and milk yield were -0.12 and -0.21 for 1966 and 1967, respectively. A negative relationship between summer weight gain of cow and milk yield has been reported in the literature (Davis and Morgan, 1943; Owen and Nielson, 1968; Todd et al., 1968; Vaccaro and Dillard, 1966; Wilson et al., 1968).

Summer weight gain of cow accounted for very little variation in milk yield for 1966 (Equation 8(a), Table 9). However, for 1967, when cow age, cow-age squared, sex and age of calf were held constant, cow summer weight gain accounted for 8.4% of variation in milk yield (Equation 8(b), Table 9). In 1967, a 10 kg gain in body weight was associated with about a 0.1 kg decrease in daily milk yield.

The higher negative relationship between summer weight gain and milk yield for 1967 vs. 1966 data resulted partly from the tendency of the HE dams to gain weight at the expense of milk yield under the limited grazing conditions of 1967.

When breed of dam was included as a constant (Equations 9(a) and (b), Table 9) the effect of summer weight gain of cow on milk yield was similar for both years.

Winter weight loss

Winter weight loss of cows as calculated for 1966 did not

appreciably influence variance in milk yield. The simple correlation between winter weight change and milk yield was -0.002.

Calf age

Earlier calving dams tended to give less milk (Equations 10(a) and (b), Table 9). Younger cows, particularly first calf heifers, tended to calve earlier than older cows. The correlations between cow age and calf age were -0.33 and -0.22 for 1966 and 1967, respectively. Since young cows milk less than older cows and had their calves earlier, the negative relationship between calf age and milk yield would appear as expected. However, for Equations 10(a) and (b), cow age and cow-age squared were included as constant variables, which should have removed most of the variation of milk yield attributable to cow age. Therefore, there may be other reasons than simply cow age causing the negative relationship between early parturition and lower milk yield. For instance, all cows were milked at the same time, hence early calving cows would be at a later stage in lactation at time of milking.

Calf sex

In 1966, the dams of male calves produced 0.26 kg more milk per day than dams of female calves. However, in 1967, this was reversed, dams of male calves yielded 0.41 kg less milk than dams of female calves. This inconsistency between years is also reflected in Equations 11(a) and (b), Table 9), when cow age, cow-age squared, weaning age of calf and breed of dam were held constant, the partial regression coefficient of milk yield on sex was positive for 1966 and negative for 1967.

It could be theorized that male calves, being somewhat heavier at

birth and more aggressive than female calves, would stimulate their dams to yield slightly more milk. Berg and Peschiera (1967) reported that Hereford cows suckling crossbred calves gave less milk in July, but about 10% more milk in October than Hereford cows suckling Hereford calves. They suggested the increased persistency of milk yield by cows suckling crossbred calves could result from greater stimulation of more frequent suckling and perhaps from more complete emptying of the udder. Melton et al. (1967) reported that cows nursing bull calves yielded 0.58 kg more milk per day at 77 days post-partum than cows nursing female calves; this difference in milk yield narrowed as the cows progressed in lactation. Other workers found no significant relationship between sex of calf and milk yield (Christian et al., 1965; Gleddie and Berg, 1968; Wilson et al., 1969).

Birth weight of calf

Birth weight was positively correlated with milk yield, 0.18 for 1966 and 0.11 for 1967. Birth weight explained only 0.0 to 2.4% of total variance in milk yield (Equations 12(a) to 14(b), Table 9), however, two of the regression coefficients were significant, $P < .05$.

Cows giving birth to heavier calves have been reported to yield more milk (Drewry et al., 1959; Melton et al., 1967; Schwulst et al., 1966). Christian et al. (1965) reported that "the small correlation of birth weight of calf and dam's milk production does not support the contention that greater birth weight of calf will increase milk production of the dam". Gleddie and Berg (1968) found little association between calf birth weight and milk yield. The present study suggests that birth weight per se is not an important factor influencing milk

TABLE 9: Percent total variance (R^2 x 100), percent additional variance (A.V.) and partial regression coefficients (b) of milk yield (kg) on several cow-calf variables

		1966 data					1967 data				
Last independent variable to enter equation (L.I.V.)	Other independent variables entered into equation†	Equation	R^2 x 100 (%)	A.V. explained by L.I.V. (%)	b L.I.V. (kg)	$S\bar{b}$ (kg)	Equation	R^2 x 100 (%)	A.V. explained by L.I.V. (%)	b L.I.V (kg)	$S\bar{b}$ (kg)
Breed of dam	a,b,c,d	1 (a)	36.4	17.9	-	-	1 (b)	48.7	32.8	-	-
Breed of dam	a,b,c,d,f	2 (a)	36.4	17.6	-	-	2 (b)	49.2	31.3	-	-
P.C.W.	a,b	3 (a)	15.3	0.0	-.0006	.0027	3 (b)	21.1	8.5	.0098**	.0021
P.C.W.	a,b,c,d	4 (a)	18.6	0.0	-.0004	.0027	4 (b)	23.6	7.7	.0094**	.0021
Cow age and $(age)^2$	g	5 (a)	15.3	7.7	-	-	5 (b)	21.1	6.6	-	-
Cow age and $(age)^2$	g,c,d	6 (a)	18.6	3.3	-	-	6 (b)	23.6	5.5	-	-
Cow age and $(age)^2$	c,d	7 (a)	18.5	9.4	-	-	7 (b)	15.9	10.1	-	-
Cow summer wt. gain	a,b,c,d	8 (a)	19.1	0.6	-.0043	.0040	8 (b)	24.3	8.4	-.0124**	.0027
Cow summer wt. gain	a,b,c,d,e	9 (a)	39.5	3.1	-.0105**	.0036	9 (b)	50.8	2.1	-.0064**	.0022
Calf age	a,b,d,e,f	10 (a)	36.4	2.9	-.0173**	.0062	10 (b)	49.2	1.8	-.0145**	.0056
Calf sex	a,b,c,e	11 (a)	36.4	0.9	.3158	.2051	11 (b)	48.7	1.8	-.3656*	.1420
Calf birth weight	c	12 (a)	10.9	2.4	.0499*	.0232	12 (b)	4.9	1.3	.0414	.0256
Calf birth weight	a,b,c,d	13 (a)	18.8	0.2	.0175	.0243	13 (b)	17.9	2.0	.0507*	.0251
Calf birth weight	a,b,c,d,e	14 (a)	36.4	0.0	.0064	.0219	14 (b)	49.2	0.5	.0280	.0201

† Independent variables held constant by forcing into equations preceding variable of interest.

code:
- a) cow age
- b) cow-age squared
- c) age of calf at weaning
- d) sex of calf
- e) breed of dam
- f) birth weight of calf
- g) postcalving weight of cow (P.C.W.)

** Significantly different from zero, $P < .01$, * $P < .05$.

yield of dam.

It would appear that one of the quickest ways to improve milk production of beef cattle would be introduction of breeds with high milk yield.

III. Factors affecting preweaning performance of progeny

A. INTRODUCTION

Since weaning weight of calf is the gross annual product of a beef cow, it is important to understand those factors that significantly contribute to this trait. In general terms, weaning weight is dependent upon birth weight, sex, age at weaning and growth rate. It is known that growth rate is related to milk yield, age and size of dam. But many of these factors are interrelated and to some extent involve the same thing. It is of interest to know:

a) the relative importance of such factors in determining preweaning performance, and

b) to measure the additional variation attributable to each factor. For example, mature cows as compared to immature cows are usually heavier, give more milk, and wean heavier calves. Examining these factors independently, it could be concluded that each was positively related to preweaning performance. However, would age or weight of dam explain any additional variation over and above that accounted for by milk yield alone?

The objectives of the present investigation were to study the joint and separate influences on calf-preweaning performance of: breed, age, weight, summer and winter-weight changes and milk yield of dam; breed of sire; and birth weight, weaning age and sex of calf. Factors influencing body weight of dam and birth weight of calf were also examined.

B. EXPERIMENTAL

This study involved 1966 and 1967 data from the University of Alberta beef breeding herd. Management and nutrition of the herd,

milking procedure and statistical methods were reported in Chapter 2. Included in the analyses were 176 and 201 cows with average ages of 5.1 and 4.3 years for 1966 and 1967, respectively.

Weights of calves were obtained at birth and October. The cows were weighed immediately after calving (P.C.W.) and again in October when their calves were weaned (W.C.W.).

The breed constitution of calves studied is given in Table 10. Breed of dam categories included: Hereford (HE), Angus and Galloway (AG), hybrid (HY) and reciprocal crosses of Hereford and hybrid (HEHY). Breed of sires included: Hereford (HE), Charolais (CH), hybrid (HY), Brown Swiss (BS) and Shorthorn (SH). The hybrids were a synthetic of Charolais, Angus and Galloway breeding.

The data were analyzed by stepwise multiple regression. Breed of dam and sire and sex of calf were entered as dummy variables in accordance with procedure described by Cohen (1968). Hereford dams, HE sires and female calves were coded as zero, hence represent reference groups or controls. The influence of cow-calf variables on calf performance to weaning were examined in respect to simple, combined and independent effects. Simple effects were considered within breed of dam, breed of sire and sex of calf subclasses. The combined effects of cow-calf variables on preweaning calf performance were studied by allowing the independent variables to enter the regression equation according to the highest partial correlation coefficient with the dependent variable. One exception was breed of dam and sire, which were forced into the equations last to allow for their sequential entry into the equations. This procedure is of interest in isolating those independent variables that contribute an important part of

TABLE 10: Number of cows by breed of sire and breed of dam category for 1966 and 1967 data

Breed of dam*	1966 Breed of sire*					1967 Breed of sire*			
	HE	CH	HY	BS	Total	HE	HY	SH	Total
HE	35	2	22	5	64	65	0	10	75
AG	8	6	37	8	59	0	27	0	27
HY	13	3	29	8	53	0	53	25	78
HEHY	0	0	0	0	0	0	0	21	21
Total	56	11	88	21	176	65	80	56	201

* HE - Hereford, AG - Angus, Galloway and their crosses, HY - Hybrid (a synthetic line of Charolais, Angus and Galloway, this group included one Brown Swiss cross in 1966 and 8 Brown Swiss crosses in 1967), HEHY - reciprocal crosses of Hereford and Hybrid lines, CH - Charolais, BS - Brown Swiss and SH - Shorthorn.

explained variance.

The independent effect of a particular cow-calf variable was studied by removing the effect of other associated variables, selected on a priori reasoning, by forcing their entry into the regression equation to precede the variable of interest. Conditional to the equations, the independent effects of breed of dam and sire, milk yield, birth weight, postcalving weight of dam (P.C.W.) and age of dam were examined. The effect of age of dam on preweaning performance of calf was found to be curvilinear, hence age squared was included as an independent variable.

Factors influencing P.C.W. and birth weight of calf were also examined and were included in the discussion of independent effects for these variables.

C. RESULTS AND DISCUSSION

Simple effects

Means and standard deviations for cow and calf data across breed were reported in Chapter 2.

(a) Cow and calf data by breed of dam category

Results and description of breed of dam categories are given in Table 11. Hybrid dams were younger than HE or AG dams, averaging approximately 4 years of age for both years. The HEHY dams appearing in 1967 were all 2 years of age. Postcalving-cow weight differences between breed categories were small except for HEHY cows which were lighter because of their age.

In 1966, HE cows gained 64 kg from postcalving to weaning. The other breed categories exceeded HE dams in summer weight gain by about

23% even though they produced more milk and weaned heavier calves. Under the more limited grazing season of 1967, HE dams gained about the same weight as during the summer of 1966 but yielded less milk and weaned lighter calves. Unlike HE, the other breed of dam categories gained considerably less weight during the summer of 1967 as compared to 1966. Milk yield also dropped but not proportionately to Herefords. Herefords yielded 21% less milk in 1967 compared to 1966, whereas the other breeds yielded 12 to 13% less milk. This observation reflected the reputation of the HE cows to retain condition at expense of milk yield while the other breed groups tended to produce milk at expense of body weight.

Average weight loss of cows from October, 1965, to postcalving, 1966, was 59 kg (Table 11). No significant breed differences were indicated. Winter weight losses for 1966-67 were not calculated. However, Berg and McElroy (1968) reported no marked difference in winter weight loss between HE and HY cows.

Average daily milk yield was 5.62 and 4.64 kg for 1966 and 1967, respectively. Differences in milk yield between breed of dam categories were highly significant. The AG and HY groups were about equal for milk yield, excelling the HE by approximately 1.20 and 1.50 kg for 1966 and 1967, respectively.

Differences in percent milk components among breed of dam categories were small and in most instances not significant (Table 11). Compared to the other breeds, milk from HY dams was somewhat lower in fat percent. In 1967, HY and HEHY were significantly higher in solids-not-fat percent relative to the HE controls.

Average birth weights of calves were 35.6 and 33.8 kg for 1966

TABLE 11: Means of cow and calf data by breed of dam category

		1966			1967			
		HE	AG	HY	HE	AG	HY	HEHY
Variable[ø]								
Dam								
No.		64	59	53	75	27	78	21
Av. age	yrs	5.34	5.66	4.19	5.20	4.44	3.90	2.00
Postcalving weight	kg	420	406	405	415	408	408	354
Summer weight gain	kg	64	77**	81**	61	51	38**	30**
Winter weight loss	kg	55	60	62	--	--	--	--
24-hour milk yield								
August	kg	5.22	6.56**	6.69**	4.62	6.20**	6.23**	4.85
October	kg	4.46	5.46**	5.59**	3.07	4.39**	4.46**	3.23
Average	kg	4.84	6.01**	6.14**	3.84	5.30**	5.35**	4.04
Milk components								
August: Fat	%	4.76	4.61	4.57	4.08	4.29	4.16	3.69
Protein	%	3.96	3.96	3.85	3.28	3.20	3.30	3.27
Solids-not-fat	%	8.92	8.98	8.92	8.51	8.62	8.78**	8.90**
October: Fat	%	5.65	5.45	5.16*	6.03	6.00	5.49**	5.57
Protein	%	3.82	3.90	3.79	3.52	3.38	3.52	3.59
Solids-not-fat	%	9.54	9.47	9.48	9.28	9.14	9.14	9.10
Calf								
Birth weight	kg	35.5	35.3	35.9	33.6	33.3	34.3	32.9
Weaning age	days	168	171	172	176	180	178	189
Weaning weight	kg	170	190**	195**	161	188**	184**	164
A.D.G. to weaning	kg	0.80	0.91**	0.92**	0.73	0.86**	0.84**	0.70
Adj. A.D.G.[¤]	kg	0.83	0.94**	0.98**	0.75	0.88**	0.89**	0.80

** Significantly different from Hereford dams $P \leq .01$, * $P \leq .05$.
¤ Adj. A.D.G. - Adjusted for age of dam.
ø Abbreviations given in text and Table 1.

and 1967, respectively. Breed of dam differences in birth weights were small and not significant.

The AG and HY groups were similar in respect to A.D.G. of calves, excelling the HE group by an average of 0.11 and 0.12 kg for 1966 and 1967, respectively. Calves from AG and HY dams excelled calves from HE dams by about 25 kg in weaning weight.

(b) Cow and calf data by breed of sire

As shown in Table 10, breeds of sires for 1966 calves were employed with some consistency across breed of dam categories. However, there was little consistency of mating pattern for 1967 calves, hence, precise separation of dam and sire effects on calf performance becomes difficult. However, some effects of breed of sire were noticed. Cow and calf data by breed of sire for 1966 and 1967 are presented in Table 12. Average age of dams by breed of sire of calf were similar except for SH sired calves which were from 2 year old dams. Calves sired by CH, HY and BS outperformed HE-sired calves. Hereford-sired calves outperformed SH-sired calves, however, they were similar when average daily gain (A.D.G.) was adjusted for age of dam.

Differences in birth weight between breed of sires were highly significant for 1966 but not significant for 1967. Average birth weights for CH, BS and HE sired calves were 41.2, 39.5 and 33.9 kg, respectively. Differences in birth weight among HE, HY and SH sires in 1967 were small and not significant (Table 12).

Dams mated to CH, HY and BS sires produced more milk than dams mated to HE sires. The partial regression coefficient of A.D.G. (kg) on milk yield (kg) was found to be approximately 0.06. Preweaning performance for breed of sire progeny groups was adjusted to milk

TABLE 12: Means of cow and calf data by breed of sire category

		1966					1967			
Breed of sire		HE	CH	HY	BS	Mean	HE	HY	SH	Mean
Dam										
No.		56	11	88	21	176	65	80	56	201
Av. age	yrs	4.93	6.36	4.68	6.67	5.10	5.69	4.68	2.00	4.26
24-hour milk yield	kg	5.09	5.95	5.86**	5.85	5.62	3.95	5.68**	3.98	4.64
Calf										
Birth weight	kg	33.9	41.2**	35.0	39.5**	35.6	33.9	34.1	33.2	33.8
Weaning age	days	175	170	165	178	170	174	177	187	179
Weaning weight	kg	176	200**	181	213**	184	163	191**	161	174
A.D.G. to weaning	kg	0.81	0.94**	0.88**	0.97**	0.87	0.74	0.89**	0.68**	0.78
Adj. A.D.G.⊠	kg	0.85	0.94**	0.93**	0.98**	0.91	0.76	0.92**	0.79	0.83

** Significantly different from Hereford sires $P \leq .01$, * $P \leq .05$.
⊠ Adj. A.D.G. - Adjusted for age of dam.

yield of dams of HE-sired calves. After adjustment, CH-, HY- and BS-sired calves still excelled HE-sired calves in A.D.G. to weaning by 0.08, 0.02 and 0.11 kg, respectively for 1966. In 1967, HY-sired calves retained an advantage of 0.05 kg in A.D.G. to weaning over HE-sired calves after adjustment for milk yield. Hereford-sired calves excelled SH-sired calves by 0.06 kg in actual average daily gain. The dams of the SH-sired calves were considerably younger, but milk yield between the two groups was similar, therefore adjustment for milk yield had no effect.

(c) Cow and calf data by sex of calf

A comparison between male and female calves for 1966 and 1967 is given in Table 13. Differences between sexes were quite similar for the two years. Compared to females, male calves were about 2 kg heavier at birth, gained 0.03 kg per day more and were 8 to 9 kg heavier at weaning. Average age of male and female calves at weaning were the same within years, 170 and 179 days for 1966 and 1967, respectively. In 1966, the dams of male calves produced 0.26 kg more milk per day than dams of female calves. However, in 1967 this was reversed, dams of male calves yielded 0.41 kg less milk than dams of female calves. Notwithstanding the lower milk yield of their dams in 1967, male calves outperformed female calves in A.D.G. from birth to weaning.

Combined effects of variables on preweaning performance

The preweaning response variables considered were A.D.G. to weaning and weaning weight. These were each regressed on several independent variables: milk yield, age, age squared, summer weight gain and

TABLE 13: Means of cow and calf data by sex of calf

	Number	Age of dam (years)	Birth weight (kg)	Milk yield (kg)	Calf age at weaning (days)	Weaning weight (kg)	A.D.G. birth to weaning (kg)
1966							
Males	92	5.1	36.7	5.75	170	188	0.89
Females	84	5.1	34.4	5.49	170	180	0.86
Difference		0	2.3	0.26	0	8	0.03
1967							
Males	87	4.4	34.9	4.41	179	179	0.80
Females	114	4.1	32.9	4.82	179	170	0.77
Difference		.3	2.0	-0.41	0	9	0.03

winter weight loss of dam; breed of sire; and birth weight, weaning age and sex of calf. Because of a close association with age of dam, P.C.W. of cow was not included in the model but was subsequently considered in some detail. The partitioning of variance and regression coefficients derived from the 4 regression equations are given in Table 14 for 1966 and 1967 data.

All considered independent variables together accounted for 73 and 70% of total variance in A.D.G. to weaning (Equations 1 and 2) and 81 and 70% of total variance in weaning weight (Equations 3 and 4) for 1966 and 1967, respectively (Table 14). Cow summer weight gain and winter weight loss could have been omitted from the model since they contributed little to explaining additional variance in preweaning performance and the partial regression coefficients were not significantly different from zero.

Milk yield accounted for a large proportion of total variance in A.D.G. to weaning, 61% for 1966 and 58% for 1967 (Equations 1 and 2, Table 14). In 1966, the main contributing variables explaining total variance in A.D.G. to weaning were milk yield and birth weight of calf which together accounted for 64% of total variance in A.D.G. or 90% of explained variance (Equation 1, Table 14). In 1967, milk yield, sex of calf and calf age at weaning together explained 65% of total variance in A.D.G. to weaning or 90% of explained variance (Equation 2, Table 14). Older calves tended to be from younger dams which partly explained the negative regression coefficients between calf age and average daily gain.

The main contributing factors in explaining total variance in weaning weight of calf were milk yield of dam and birth weight,

weaning age and sex of calf (Equations 3 and 4, Table 14). There was considerable between year difference in relative proportion of variance in weaning weight explained by each of these factors. In 1966, milk yield of dam and age and birth weight of calf together explained 75% of total variance in weaning weight. Calf age and birth weight, respectively accounted for an additional 38 and 12% to total variance over milk yield. In 1967, milk yield of dam and birth weight, age and sex of calf accounted for 65% of total variance in weaning weight. Birth weight added only 8.5% and calf age added 6.1% to total variance of weaning weight above milk yield (Equation 4, Table 14).

Between year differences reflect both environmental and breed differences. It will be recalled that CH and BS sires were used in 1966 but not in 1967. Since breed of sire and dam entered the equations last by forcing all other variables, additional variance in weaning weight explained by birth weight in 1966 could largely be a reflection of differences in sires.

Drewry et al. (1959) reported that "lactation number, mothering score, average daily milk production of the dam, birth weight, age and suckling time of calf accounted for 75, 77 and 60% of the variability associated with total gain of calf up to one, three and six months of age, respectively". Correlations between milk yield and calf gain reported by these workers were considerably lower than those found in the present study. Neville (1962) found that effects of year, nutrition, sire, sex, milk, birth order of calf, birth weight of calf and weight and age of dam accounted for 82% of total variance in calf gain. He reported that 66% of total variation in 8 month calf weight

TABLE 14: Percent total variance (R^2 x 100), percent additional variance (A.V.) and partial regression coefficients (b) of preweaning performance sequentially regressed on several cow-calf variables recorded in 1966 and 1967

Equation	Dependent variables		Milk yield (kg)	Calf birth weight (kg)	Calf age (days)	Cow age (years)	Cow age squared	Sex	Cow summer weight gain (kg)	Cow winter weight loss (kg)	Breed† of dam and sire
			Independent variables								
1.	1966 A.D.G. to weaning										
	Order of entry‡		1	2	4	5	6	7	8	3	9
	R^2 x 100	%	60.5	64.0	65.7	65.9	66.3	66.4	66.5	65.2	72.6
	A.V.	%	-	3.5	0.5	0.2	0.4	0.1	0.0	1.2	6.1
	b	kg	0.0507**	0.0018	0.0005	0.0426*	-0.0039*	0.0207	-0.0003	0.0003	-
2.	1967 A.D.G. to weaning										
	Order of entry		1	6	3	4	5	2	7		8
	R^2 x 100	%	58.0	68.8	65.3	66.5	68.1	63.2	70.2		70.3
	A.V.	%	-	0.7	2.1	1.2	1.6	5.2	1.4		0.1
	b	kg	0.0611**	0.0035*	-0.0013**	0.0405*	-0.0033	0.0514**	-0.0001		-
3.	1966 weaning weight										
	Order of entry		1	3	2	5	6	8	7	4	9
	R^2 x 100	%	25.1	75.2	63.3	75.9	76.4	76.5	76.4	75.6	81.3
	A.V.	%	-	11.9	38.2	0.3	0.5	0.1	0.0	0.4	4.8
	b	kg	8.3930**	1.2951**	0.9577**	9.1160**	-0.8190**	3.070	-0.0685	0.0523	-
4.	1967 weaning weight										
	Order of entry		1	2	3	5	6	4	7		8
	R^2 x 100	%	46.9	55.4	61.6	66.8	68.7	65.4	68.8		70.1
	A.V.	%	-	8.5	6.1	1.4	1.9	3.9	0.1		1.3
	b	kg	10.949**	1.6176**	0.5663**	7.9000*	-0.6470*	9.8100**	-0.0220		-

† Entered the regression equation last by forcing all other variables.
‡ Indicates order in which forced variables were entered into the regression equation.
** Significantly different from zero $P \leq .01$, * $P \leq .05$.

was attributable to differences in milk consumption. Gleddie and Berg (1968) reported that milk yield accounted for 71% of variance in calf average daily gain. Linton et al. (1968) reported that year, sex of calf and age of dam, respectively accounted for 4.34, 8.41 and 5.67% of total variance in age-adjusted weaning weights of calves. The interactions of the main effects as reported by these workers each explained less than 1% of total variance in adjusted weaning weight.

Independent effects of variables on preweaning performance

(a) Breed of dam

As shown in Table 15 breed of dam had considerable influence on preweaning performance of calf. Holding cow age, cow age squared, age and sex of calf constant, breed of dam differences explained an additional 23% of total variance in A.D.G. to weaning for both years (Equations 1 and 2). As indicated in Equations 3 and 4, response of weaning weight to breed of dam was similar to average daily gain. Most of the variation in preweaning performance explained by breed of dam was the result of differences in milk yield between breeds. When milk yield was included in the model as a constant variable, breed of dam explained only from 0.8 to 2.6% of total variation in preweaning performance of calf (Equations 5 to 8, Table 15).

(b) Breed of sire

Breed of sire had little influence on preweaning performance in 1967. Primarily because of the higher growth rate of calves sired by CH and BS, breed of sire had more influence on preweaning performance in 1966. Holding constant milk yield, age, age squared, P.C.W. and weight changes of cow and age and sex of calf, breed of sire

TABLE 15: Percent total variance (R^2 x 100) and percent additional variance (A.V.) of calf performance to weaning explained by breed of dam and breed of sire holding certain specified variables constant

Equation	Year	Dependent variables	Independent variables held constant ‡	R^2 x 100 (%)	A.V. explained by last independent variables to enter equation				
					Dams				
					HY (%)		AG (%)	HEHY (%)	All (%)
1.	1966	A.D.G. to weaning	a,b,c,d	40.2	11.4		11.5	--	22.9
2.	1967	A.D.G. to weaning	a,b,c,d	48.7	12.5		5.0	5.3	22.8
3.	1966	Weaning weight	a,b,c,d	61.4	9.3		7.1	--	16.4
4.	1967	Weaning weight	a,b,c,d	50.8	13.1		4.7	4.7	22.5
5.	1966	A.D.G. to weaning	a,b,c,d,e	67.0	1.4		1.2	--	2.6
6.	1967	A.D.G. to weaning	a,b,c,d,e	69.0	0.2		0.3	0.4	0.9
7.	1966	Weaning weight	a,b,c,d,e	70.1	1.6		1.0	--	2.6
8.	1967	Weaning weight	a,b,c,d,e	64.8	0.3		0.3	0.2	0.8
					Sires				
					BS (%)	CH (%)	HY (%)	SH (%)	All (%)
9.	1966	A.D.G. to weaning	a,b,c,d,e,f,g,h	71.3	3.6	0.8	1.3	--	5.7
10.	1967	A.D.G. to weaning	a,b,c,d,e,f,g	69.9	--	--	1.4	0	1.4
11.	1966	Weaning weight	a,b,c,d,e,f,g,h	77.1	4.1	1.3	1.4	--	6.8
12.	1967	Weaning weight	a,b,c,d,e,f,g	66.4	--	--	1.3	0	1.3

‡ Independent variables held constant by forcing into regression equation first.

code: a) age of dam; b) age squared of dam; c) age of calf; d) sex of calf; e) milk yield; f) postcalving weight of dam; g) summer weight gain of dam; h) winter weight loss of dam

differences explained an additional 5.7 and 1.4% of total variance in A.D.G. to weaning and 6.8 and 1.3% of total variance in weaning weight for 1966 and 1967, respectively (Equations 9 to 12, Table 15). Because of the high maternal influence on preweaning performance, sire influence on earlier stages of calf growth may be minimal. Knapp and Black (1941) reported no significant difference in growth rate to weaning between progeny groups of different sires. Neville (1962) reported no significant difference in growth rate to weaning between progeny groups of 5 Hereford sires. Pahnish et al. (1969) reported highly significant differences in A.D.G. to weaning between sire progeny groups when Hereford, Angus and Charolais sires were used across the same breed combination of dams. They reported that Charolais sired calves outperformed Hereford sired calves by 0.059 and 0.079 kg in A.D.G. to weaning for males and females, respectively. They did not find significant differences in A.D.G. of progeny within sire breeds. The results of these workers are in general agreement with the present study.

(c) Milk yield

Of all factors studied, milk yield had the most influence on preweaning performance. The correlations of milk yield with A.D.G. to weaning were 0.78 and 0.76 for 1966 and 1967, respectively. Correlations between milk yield and A.D.G. have been reported ranging from 0.58 to 0.85 (Furr and Nelson, 1964; Gleddie and Berg, 1968; Melton et al., 1967a; Neville, 1962; Schwulst et al., 1966; Wilson et al., 1968).

The effect of milk yield on preweaning performance is shown in

Equations 1 to 4, Table 16 where calf age and sex were held constant. Response of calf performance to differences in milk yield were slightly greater for 1967 as compared to 1966, possibly a reflection of the drier conditions for 1967. Milk yield explained 56 to 59% of total variation in A.D.G. to weaning and 42 to 57% of total variation in weaning weight. An increase of 1 kg per day in milk yield resulted in 11.3 to 14.6 kg increase in weaning weight of calf (Equations 3 and 4). The interrelationship of cow age and milk yield is shown in Equations 5 to 8, Table 16. When cow age was included in the model, additional variance of calf performance explained by milk yield was reduced by about 12%. However, the partial regression coefficients remained relatively similar. When breed of dam and sire of calf were included in the model as constant variables, milk yield still accounted for about 20% of total variance in calf preweaning performance (Equation 9 to 12, Table 16), which suggests considerable variation of milk production between cows of similar age and breed. Factors influencing milk yield have been discussed in the previous chapter.

(d) Birth weight of calf

Birth weight of calves may be important in influencing preweaning performance. The simple correlations between birth weight and A.D.G. of calf to weaning for the present study were 0.32 and 0.23 for 1966 and 1967, respectively. The simple correlations between birth weight and weaning weight were 0.41 and 0.37 for 1966 and 1967, respectively. Correlations between birth weight and A.D.G. have been reported ranging from 0.07 to 0.52 and between birth weight and weaning weight from 0.27 to 0.62 (Christian et al., 1965, Drewry et al., 1959;

TABLE 16: Percent total variance (R^2 x 100), percent additional variance (A.V.) and partial regression coefficients (b) of preweaning performance regressed on milk yield (kg) holding other specified variables constant

Equation	Year	Dependent variables	Independent variables held constant‡	R^2 x 100 (%)	A.V. explained by milk yield (%)	b (kg)	$S_{\bar{b}}$ (kg)
1.	1966	A.D.G. to weaning	a,b	62.0	58.6	0.0638**	0.0039
2.	1967	A.D.G. to weaning	a,b	65.3	55.5	0.0786**	0.0044
3.	1966	Weaning weight	a,b	63.9	42.3	11.308**	0.796
4.	1967	Weaning weight	a,b	60.6	56.7	14.628**	0.868
5.	1966	A.D.G. to weaning	a,b,c,d	63.8	46.5	0.0600**	0.0041
6.	1967	A.D.G. to weaning	a,b,c,d	68.1	42.2	0.0725**	0.0045
7.	1966	Weaning weight	a,b,c,d	67.3	31.1	10.228**	0.805
8.	1967	Weaning weight	a,b,c,d	64.1	42.5	13.401**	0.882
9.	1966	A.D.G. to weaning	a,b,c,d,e	71.3	27.4	0.0526**	0.0042
10.	1967	A.D.G. to weaning	a,b,c,d,e	69.6	18.9	0.0629**	0.0058
11.	1966	Weaning weight	a,b,c,d,e	75.9	18.1	8.914**	0.801
12.	1967	Weaning weight	a,b,c,d,e	65.5	19.6	11.805**	1.137

‡ Independent variables forced to enter regression equation first.
Code: a) age of calf
b) sex of calf
c) age of dam
d) age squared of dam
e) breed of sire and dam of calf
** Significantly different from zero, $P \leq .01$.

Gregory et al., 1950; Swiger et al., 1962).

Holding milk yield, age and age squared of dam and age and sex of calf constant, the partial regression coefficients for preweaning response variables on birth weight were all positive and in most instances significant ($P < .01$ to $P < .05$) (Table 17).

Subject to the conditions of the regression model, birth weight accounted for an additional 8.8 and 4.7% of total variance in weaning weight for 1966 and 1967, respectively (Equations 3 and 4, Table 17). Calves with heavier birth weights tended to have a slightly higher rate of gain. An increment of 1 kg in birth weight was associated with an increase in weaning weight of 1.74 and 1.59 kg for 1966 and 1967, respectively (Equations 3 and 4, Table 17). Vaccaro and Dillard (1966) found that 1 kg additional birth weight accounted for 1.9 and 0.8 kg additional calf weight at 180 days of age for two sets of data, respectively. Christian et al. (1965) suggested the association between birth weight and weaning weight to be more than a part-whole relationship. Neville (1962) reported that calves 1 lb heavier at birth have a similar advantage at 4 months and 8 months of age.

Although not shown in the tables, partitioning of variance of birth weight was calculated by regression on sex, P.C.W., cow age, cow age squared, winter weight loss (1966 only) and breed of dam and breed of sire of calf. All variables together accounted for 35.7 and 18.4% of total variance in birth weight for 1966 and 1967, respectively. Differences between P.C.W., sex, winter weight loss and breed of sire explained 14.4, 6.7, 3.7 and 10.3% of total variance in birth weight, respectively for 1966. Together these 4 variables accounted

TABLE 17: Percent total variance (R^2 x 100), percent additional variance (A.V.) and partial regression coefficients (b) of preweaning response variables regressed on birth weight of calf (kg) with milk yield, age and age squared of dam and age and sex of calf held constant

Equation	Year	Dependent variables	R^2 x 100 (%)	A.V. explained by birth weight of calf (%)	b (kg)	$S_{\bar{b}}$ (kg)
1.	1966	A.D.G. to weaning	66.0	2.3	.0042**	.0013
2.	1967	A.D.G. to weaning	68.8	0.7	.0033*	.0016
3.	1966	Weaning weight	76.2	8.8	1.7350**	.2193
4.	1967	Weaning weight	68.7	4.7	1.5910**	.2956

** Significantly different from zero $P \leq .01$, $*P \leq .05$.

for 98% of the explained variance in birth weight. For 1967 data, differences between sex, P.C.W. and cow age explained 7.4, 6.7 and 2.6% of total variance in birth weight, respectively or together they accounted for 90% of the explained variance in birth weight.

Postcalving weight of cow appeared to affect birth weight considerably more than cow age. The partial regression coefficients for birth weight (kg) regressed on P.C.W. (kg) were 0.0264 ($P < .01$) and 0.0263 ($P < .01$) for 1966 and 1967, respectively. The partial regression coefficients for birth weight on cow age were negative for both years and not significant. Knapp et al. (1940) found length of gestation, calving sequence and weight of dam to account for 38% of the variance in birth weight, and length of gestation accounted for about 80% of explained variance. Brown and Galvez (1969) reported sire effect to account for 20 and 9.5% and dam effect to account for 17.6 and 9.3% of total variance in birth weight for Hereford and Angus cattle, respectively. These workers indicated that age of dam accounted for about 6% of total variance in birth weight of progeny.

Singh et al. (1970) reported that cows with heavier calves at birth had longer calving intervals. It is of interest to note that the HY line of the University of Alberta herd were approximately equal in birth weight to HE but gained considerably faster to weaning. The HY line, which is a synthetic of Charolais, Angus and Galloway, have maintained a birth weight approaching the parental mean of the three breeds. In a crossing program, the incorporation of a breed with a relatively low birth weight may have an advantage in respect to minimizing difficult delivery at birth and possible subsequent fertility problems.

There appears to be a positive relationship between birth weight of calf and growth rate. However, deliberate selection for heavier birth weights would be a questionable procedure considering the possibility of augmenting calving difficulties.

(e) Postcalving weight of dam

Postcalving weight of cow was used as the standard measure of cow size in this study. The simple correlations between P.C.W. and A.D.G. of calf to weaning calculated within breed and age of dam subclasses, were generally low and in most instances, not significantly different from zero ($P < .05$). Sixteen of the coefficients were positive and four were negative (not shown in tables).

Percent variance and partial regression coefficients of A.D.G. to weaning and weaning weight each regressed on P.C.W. with other specified independent variables held constant, are given in Table 18, Equations 1 to 14. Subject to the conditions of the model for 1966, P.C.W. explained only an additional 0.6 to 1.5% of total variance of the preweaning response variables. However for 1967, P.C.W. explained an additional 0.3 to 8.5% of total variance in preweaning response variables. As indicated in Table 18, when milk yield was included as a constant variable, response of preweaning performance to P.C.W. was similar for both years. When breed of dam and breed of sire (both singly and together) were included as constant variables either alone or together along with age, age squared and milk yield of dam and age and sex of calf, breed effect had little influence on the response of postweaning performance of progeny to postcalving weight of dam (Equations 5 to 10, Table 18). The partial regression coefficients of

TABLE 18: Percent total variance ($R^2 \times 100$), percent additional variance (A.V.) and partial regression coefficients (b) of preweaning response variables regressed on P.C.W. (kg) holding other specified variables constant

Equation	Year	Dependent variables	Independent variables held constant ǂ	$R^2 \times 100$ (%)	A.V. explained by PCW (%)	b (kg)	$S_{\bar{b}}$ (kg)
1.	1966	A.D.G. to weaning	a,b,c,d	18.0	0.8	.00027	.00021
2.	1967	A.D.G. to weaning	a,b,c,d	32.5	6.6	.00089**	.00020
3.	1966	A.D.G. to weaning	a,b,c,d,e	64.7	0.9	.00029*	.00014
4.	1967	A.D.G. to weaning	a,b,c,d,e	65.1	0.4	.00023	.00015
5.	1966	A.D.G. to weaning	a,b,c,d,e,f	67.8	0.8	.00029*	.00014
6.	1967	A.D.G. to weaning	a,b,c,d,e,f	69.3	0.3	.00021	.00015
7.	1966	A.D.G. to weaning	a,b,c,d,e,g	70.7	0.7	.00026*	.00013
8.	1967	A.D.G. to weaning	a,b,c,d,e,g	69.9	0.4	.00023	.00014
9.	1966	A.D.G. to weaning	a,b,c,d,e,f,g	72.0	0.6	.00026	.00013
10.	1967	A.D.G. to weaning	a,b,c,d,e,f,g	70.0	0.4	.00023	.00015
11.	1966	Weaning weight	a,b,c,d	37.6	1.3	.07278	.03866
12.	1967	Weaning weight	a,b,c,d	30.1	8.5	.18584**	.03816
13.	1966	Weaning weight	a,b,c,d,e	68.8	1.5	.07703**	.02742
14.	1967	Weaning weight	a,b,c,d,e	65.1	1.0	.06657*	.02837

ǂ Independent variables forced to enter regression equation first.

code:
a) age of dam
b) age squared of dam
c) age of calf
d) sex of calf
e) milk yield
f) breed of dam of calf
g) breed of sire of calf

** Significantly different from zero, $P \leq .01$, * $P \leq .05$.

A.D.G. (kg) to weaning on P.C.W. (kg) were 0.00027 (not significant) and 0.00089 (significant at $P < .01$) for 1966 and 1967, respectively (Equations 1 and 2, Table 18). When milk yield was included as a constant variable, the partial regression coefficients for A.D.G. to weaning on P.C.W. were similar for the two sets of data (Equations 3 and 4, Table 18). The regression coefficients for weaning weight (kg) on P.C.W. (kg) were 0.07278 (not significant) and 0.18584 ($P < .01$) when milk yield was not held constant and 0.07703 ($P < .01$) and 0.06657 ($P < .05$) when milk yield was held constant (Equations 11 to 14, Table 18).

Considering the influence of P.C.W. of cow statistically independent of age, milk yield and breed of dam and age and sex of calf, these results suggest that 10 kg additional P.C.W. of cow would be associated with about 0.7 kg additional weaning weight of calf which is in general agreement with a number of other workers. McDonald and Turner (1969) reported a 100 kg increase of dam's weight resulted in 11.77 kg additional weaning weight. Ewing et al. (1967) reported a 9.78 kg increase in weaning weight per 100 kg increase in dam's weight. Fitzhugh (1965) reported the average increase in weaning weight to range from 0.73 to 11.65 lbs for every 100 lb increment in P.C.W. of dam. Tanner et al. (1965) reported weaning weight increments of 8.5 and 4.9 lb for Angus and Hereford dams, respectively for each 100 lb increment in body weight. Neville (1962) reported a 7 lb increase in weaning weight per 100 lb increase in body weight of dam. Nichols and Whiteman (1966), working with sheep, found 70 day lamb weight to increase by 0.07 kg for each 1 kg additional weight of yearling ewes. Ray and Smith (1966) reported a 1 kg increment in ewe

weight to be associated with a 0.10 kg increase in lamb weaning weight.

Other workers found either no association or very little association between preweaning performance and body weight of cow (Godley and Tennant, 1969; Gregory et al., 1950; Hawkins, et al., 1965; Melton et al., 1967b; Wilson et al., 1969).

Although not shown in the tables, weight of cow at weaning time of calf (W.C.W.) was compared with P.C.W. in respect to association with A.D.G. of calf. Simple correlations between W.C.W. and A.D.G. to weaning were 0.29 and 0.35 for 1966 and 1967, respectively. Correlations between P.C.W. and A.D.G. were slightly higher, 0.33 and 0.44 for 1966 and 1967, respectively. Holding constant: age, age-squared and breed of cow and sex, age and breed of sire of calf; W.C.W. explained an additional 0.2 and 0.4% of total variance of A.D.G. for 1966 and 1967, respectively, whereas P.C.W. explained an additional 0.4 and 2.0 percent. The partial regression coefficients for A.D.G. (kg) regressed on W.C.W. (kg) were -0.0001 and 0.0002 for 1966 and 1967, respectively, whereas the partial regression coefficients for A.D.G. (kg) regressed on P.C.W. (kg) were 0.0002 and 0.0005 ($P < .01$).

Although association of both variables with preweaning performance was small it appeared that P.C.W. was more highly associated with A.D.G. of calf than cow weight at weaning time of calf. This may reflect the negative relationship between summer weight gain and milk yield. Similar findings have been reported elsewhere (Fitzhugh, 1965; Gregory et al., 1950; Vaccaro and Dillard, 1966).

Cow age (linear and quadratic) alone accounted for 59% of total variance in P.C.W. of cow. This relationship was essentially linear; cow age squared only added 5.4 and 1.1% in explaining total variance

of P.C.W. over cow age for 1966 and 1967, respectively. When included in the model, breed of dam explained only an additional 3.5% of total variance in P.C.W. of cow. Calving date and winter weight loss of cow explained very little of the variance in postcalving weight. There was very little between year difference in respect to partitioning variance in postcalving weight. Total variance of P.C.W. explained by all independent variables included in the model was 63% for both years (not shown in tables).

(f) Cow age

As cows mature, they become heavier, produce more milk and raise faster gaining calves. In 1967, calves from 4 year old cows gained 0.10 kg per day faster than calves from first calf heifers. In 1966, this difference was 0.17 kilograms. It is of interest to examine the interrelationships of P.C.W. and cow age with preweaning performance of calf. Percent variance and partial regression coefficients of A.D.G. to weaning are given for 8 regression equations (Table 19). Cow age and age squared alone accounted for 15.2 and 22.7% of total variance in A.D.G. for 1966 and 1967, respectively (Equations 1 and 2, Table 19). Holding milk yield constant, cow age and cow age squared explained an additional 0.9 and 4.9% of total variance in A.D.G. for 1966 and 1967, respectively (Equations 3 and 4, Table 19). Postcalving weight alone accounted for 10.9 and 18.8% of total variance in A.D.G. for 1966 and 1967, respectively (Equations 5 and 6, Table 19). Holding milk yield constant, P.C.W. accounted only for an additional 1.4 and 2.4% of total variance in A.D.G. for 1966 and 1967, respectively (Equations 7 and 8). These results suggest

TABLE 19: Percent total variance (R^2 x 100), percent additional variance (A.V.) and partial regression coefficients (b) of A.D.G. of calf to weaning regressed on age and age of cow squared, P.C.W., and milk yield

Independent variables		1966 Equation	1966 R^2 x 100 (%)	1966 A.V. (%)	1966 b (kg)	1967 Equation	1967 R^2 x 100 (%)	1967 A.V. (%)	1967 b (kg)
Cow age†	yrs	1.	10.0	--	.0893**	2.	10.1	--	.1140**
Cow age squared†			15.2	5.2	-.0075**		22.7	12.6	-.0117**
Postcalving weight	kg		15.7	0.5	.0002		28.7	5.8	.0008**
Milk yield†	kg	3.	60.5	--	.0586**	4.	58.0	--	.0695
Cow age	yrs		61.0	0.5	.0295		60.5	2.5	.0698**
Cow age squared			61.4	0.4	-.0025		62.9	2.4	-.0061**
Postcalving weight†	kg	5.	10.9	--	.0002	6.	18.8	--	.0008**
Cow age	yrs		12.1	1.2	.0893**		28.5‡	8.6	.1140**
Cow age squared			15.7	3.6	-.0075**		19.9	1.1	-.0117**
Milk yield†	kg	7.	60.5	--	.0590**	8.	58.0	--	.0714**
Postcalving weight	kg		61.9	1.4	.0002*		60.4	2.4	.0004**

† Variables forced to enter regression preceding other variables.
‡ Cow age entered equation last.
** Significantly different from zero, $P \leq .01$, * $P \leq .05$.

that about 80% of the variance in A.D.G. explained by either cow age or P.C.W. can be accounted for by the difference in milk yield associated with either of these two variables. This is in agreement with Singh et al. (1970).

Holding cow age and cow age squared constant, P.C.W. accounted for 0.5 and 5.8% of the variance in A.D.G. for 1966 and 1967, respectively (Equations 1 and 2, Table 19). Holding P.C.W. constant, cow age and cow age squared accounted for 4.8 and 9.7% of total variance in A.D.G. for 1966 and 1967, respectively (Equations 5 and 6, Table 19). Cow age appears to have a greater influence on A.D.G. than postcalving weight. It may be inferred that physiological changes associated with maturity other than size of dam could have some influence on preweaning performance of progeny. This may largely be a reflection of an association between maturity and milk production independent of size. Or, as suggested by Fitzhugh (1965), body weight, because of its reflection of condition, may not be a good measurement of size. Body measurements as measures of cow size will be considered in a subsequent chapter.

IV. Factors affecting progeny performance to 365 days of age

A. INTRODUCTION

The association of cow size with performance of progeny has important economic implications to the cattle industry. As discussed in Chapter 3, there was a low positive association between cow body weight and preweaning performance of calf. It was shown that a 10 kg increase in postcalving weight of dam would result in about a 0.7 kg increase in weaning weight of calf. Although an economic study is to be the subject of a later chapter, a preliminary marginal analysis suggested that expected revenue from additional weaning weight of calf associated with the larger dam would not be of sufficient magnitude to offset the cost of maintaining the additional body weight of the larger dam. However, it is important to know if growth rate of progeny associated with size of dam continues over the postweaning feeding period, if so, the net efficiencies of such could be credited to the larger cow.

It was the purpose of the present study to investigate the physical relationship of postcalving weight of dam, breed effect, birth weight and preweaning performance of calf with performance of calf to 365 days of age.

B. EXPERIMENTAL

The present investigation involved 4 years of data from the University of Alberta beef breeding herd. Separate analysis was carried out for 1966-67, 1967-68 and 1968-70 data (1968-69 and 1969-70 data were combined).

Calves were born in the spring and weaned by mid-October at a

mean age ranging from 167 to 180 days between years. The postweaning feeding period was for approximately 185 days.

The breeding pattern for 1966-67 and 1967-68 was quite complex varying considerably between years with disproportionate cell frequencies within years. The 1966 calves were from Hereford (HE), Hybrid (HY), Charolais (CH), and Brown Swiss (BS) sires mated across HE, Angus and Galloway (AG) and HY dams. The 1967 calves were from HE, Shorthorn (SH) and HY sires mated across HE, AG, HY and Hereford x Hybrid and reciprocal cross (HEHY) dams. For 1967-68, SH sired female calves, all from two year old dams, received different postweaning treatment, hence were eliminated from the analysis. For 1968-70 data, the breeding pattern was simplified by including only HE and HY calves. The hybrids were a synthetic of Aberdeen Angus, Galloway and Charolais breeding.

Management and nutrition of the cow herd to 1968 was reported by Berg and McElroy (1968). For the period, 1968-70 the breeding herd was separated into 3 groups for wintering: wet mature cows (those that had nursed calves the previous summer), yearlings and wet 2-year olds, and dry cows. From early January until late March the weekly feed allowance for all cows consisted of 34 kg of straw, up to 7.3 kg of hay depending on the severity of the weather and with exception of dry cows, 13.6 kg of grain consisting of a 3:1 mixture of barley and oats and 0.91 kg of a 24% protein pellet fortified with minerals and Vitamin A.

In addition the cows were administered injections of 2×10^6 international units of Vitamin A in 2 doses, one in late fall and the other prior to calving. Heifers were given the hay allowance

regardless of weather conditions.

The winter of 1968-69 was extremely severe with temperatures dropping below zero on 75 days and remaining below zero on 44 days, (Berg, 1971). This worker reported body weight losses over winter as 54 and 28 kg for mature and 2-year old cows, respectively which was considerably higher than anticipated.

During summer, pasture was provided with no additional supplement except for nursing 2-year old cows which were given 12.3 kg of grain per head per week for 4 weeks prior to the breeding season.

Calves were not creep fed. After weaning all calves were given a "booster" vaccination as protection against blackleg and malignant oedema, a systemic treatment for lice and warble control, and 1 cc of injectable Vitamin A, D, and E containing 500,000, 75,000 and 50 international units, respectively.

After weaning, all calves were placed on an adjustment ration for a minimum of two weeks, which consisted of 1.4 kg of oats per head per day plus hay provided on a free choice basis. For 1966-67, heifers were continued on this ration over the feeding period. For 1967-68, oats were increased to 2.3 kg per head per day by January. The 1968-70 female calves were fed similar amounts of grain as in 1966-67 but the grain consisted of a 1:3 oat-barley mixture by weight.

Male calves were fed a 1:3 rolled oat-barley grain mixture at a gradually increasing rate until calves were on full feed. Cut hay was initially fed at 1.8 kg per head per day and reduced to 0.9 kg as animals approached full feed.

The grain portion of all rations was supplemented with 5% of a 24% protein supplement fortified with calcium, phosphorus and

Vitamins A and D. Cobalized-iodized salt was provided.

Essentially, male calves were fed a finishing ration ad libitum, for a mean postweaning average daily gain (PWADG) ranging from 1.2 to 1.4 kg between years. Female calves were fed a restricted ration for a mean PWADG ranging from 0.51 to 0.66 kg between years. For this reason, the data were analyzed separately by sex of calf.

The data were analyzed by stepwise multiple regression as previously described. The multiple regression equations were developed by holding statistically constant certain independent variables selected on a priori reasoning for the purpose of examing the direct effect of a particular variable of interest. Within designated statistical conditions, the direct effect of birth weight (BW) and breed of calf and postcalving weight of dam (PCW) were examined in relation to preweaning and postweaning performance of calf. The relationship of preweaning and postweaning performance of calf was also studied.

C. RESULTS AND DISCUSSION

The breed grouping and means for age and PCW of dam and BW, average daily gain to weaning (ADG) and PWADG for male and female calves are shown in Table 20 for 1966-67, 1967-68 and 1968-70 data. The overall means and standard deviations for the above variables are also given in Table 20 by sub-class of year and sex of calf. Differences in PCW between breeds were small and in most instances not significant ($P < .05$). The standard deviations of PCW means were relatively consistent between years and calf sex subclasses, ranging from 56 to 71 kilograms. Mean age of dams ranged from 4.4 to 5.7

years by year and sex of calf subclasses. Variation of BW was greater in the 1966-67 group than in other years which was primarily a reflection of CH and BS sires used that year. Differences in birth weight across breed of dam were small and not significant ($P < .05$). Male calves exceeded female calves by 2 kg in birth weight for 1966-67 and 1967-68 and by 1 kg for 1968-70 data. Calves from HY and AG dams tended to consistently exceed calves from HE dams in ADG to weaning which, as indicated in Chapter 3, was largely a reflection of higher milk yield. Average daily gain to weaning was 0.89, 0.80 and 0.96 kg for male calves and 0.86, 0.81 and 0.87 kg for female calves for 1966-67, 1967-68 and 1968-70, respectively. Compared to HE controls differences in PWADG for calves of other breed combinations were generally not significant ($P < .05$). Postweaning average daily gain for male calves was 1.22, 1.40 and 1.35 kg and for female calves 0.68, 0.65 and 0.51 kg for the three time periods, respectively.

Birth Weight

Calves heavier at birth tended to excel in both preweaning and postweaning rate of growth. As indicated in Table 21, with exception of 1967-68 male calves, correlations between BW and ADG to weaning ranged from 0.24 to 0.45. The low correlation between BW and ADG to weaning ($r = 0.09$) for 1967-68 males can probably be accounted for by HE calves which were above average in BW but below average in average daily gain. Correlations between BW and PWADG for male calves ranged from 0.20 to 0.36. Correlations between BW and PWADG for female calves were somewhat lower, attributable to the restricted postweaning ration which tended to hold heavy calves back more than light calves.

The partial regression coefficients of ADG to weaning and PWADG regressed on BW and percent additional variance of ADG to weaning and PWADG explained by BW are given in Equations 1a to 6a and 1b to 6b, Table 22 by sex of calf and year. The response of ADG to weaning to BW for male calves was low and similar between years, accounting for only 0.4 to 0.9% additional variance in ADG to weaning. The response of ADG to weaning to BW was considerably higher for female calves, accounting for 2.4 to 5.1% of additional variance in ADG to weaning.

The possibility arises that this apparent sex difference in BW-growth response could be attributable to confounding with heterosis. It has been reported by Urick et al. (1968) that heifers show a greater response to heterosis than male calves. They reported this difference being small for birth weight, 3.7 vs. 3.0%, however, the difference of heterotic response for weaning weight was considerable, 9.0 vs. 4.9 percent. For the 1968-70 data which was relatively simple to separate by breed, the response of ADG to weaning to BW was considerably higher for female calves of either HE or HY breeding, b = 0.0032 $\pm$ .0036 and 0.0025 $\pm$ .0031, respectively for the HE and HY male calves and b = 0.0083 $\pm$ .0044 and 0.0120 $\pm$ .0032 (significant $P < .01$) for HE and HY female calves, respectively (not shown in tables). These results suggest that sex differences in BW-growth response may be, in part, influenced by heterosis but also, in part, attributable to direct sex influence.

Response of PWADG to BW was generally greater than response of ADG to weaning to birth weight. Birth weight explained an additional 3.6 to 9.4% of total variance in PWADG (Equations 1b to 6b, Table 22). The partial regression coefficients of PWADG with BW were somewhat

higher for male calves compared to female calves as would be expected with female calves on a restricted ration, however, there was little between sex difference in percent additional variance of PWADG, explained by birth weight. Had female calves been fed to appetite, one might expect the preweaning trend of sex difference in BW-growth response to continue into the postweaning period. A summary of these results is given in Table 23. Compared to male calves, the higher preweaning response of ADG to weaning to BW tended to be offset by the lower postweaning response for female calves resulting in little sex difference at 365 days of age. A 1 kg increase in BW was associated with a range of 2.86 to 4.42 kg increase in calf weight at 365 days of age (Table 23). The lower BW-growth response for 1966-67 possibly can be attributable to breed difference. Compared to the other two periods, because of CH and BS sires, the variance of BW was greater for 1966-67, however, the variance of ADG to weaning and PWADG were similar across years.

Postcalving Weight of Cow

The simple correlations between PCW of dam and ADG of calf to weaning ranged from 0.29 to 0.38 (Table 21). This association, however, includes interrelationships between PCW, cow age and milk yield and hence does not represent a direct influence of PCW on average daily gain of calf to weaning. Correlations between PCW and PWADG were low, varying from positive to negative (Table 21).

The partial regression coefficients of ADG to weaning and PWADG with PCW and percent additional variance of ADG to weaning and PWADG explained by PCW are given in Equations 7a to 12a and 7b to 12b,

Table 22, by calf sex and year. For 1967-68 and 1968-70 data, the response of ADG to weaning and PWADG of male calves to PCW was similar accounting for an additional 1.1 to 1.8% and 1.9 to 2.7% of total variance in ADG to weaning and PWADG, respectively. For the same years, the partial regression coefficients for ADG to weaning (kg) and PWADG (kg) with PCW (10 kg) ranged from 0.0039 to 0.0051 and 0.0065 to 0.0068 respectively (Equations 9a, 11a, 11b and 9b, Table 22). For 1966-67 male calves, the regression coefficient for ADG to weaning with PCW was small and negative. Average daily gain to weaning of female calves showed little response to PCW for 1968-70, slightly greater response than male calves for 1967-68 and considerable response for 1966-67, b = 0.0078 significant $P < .01$ (Equations 8a, 10a and 12a, Table 22).

As shown in Table 20, for 1966-67 data, breeding pattern, mean cow age and cow body weight were similar for male and female calves as expected. The difference in response of ADG to weaning to PCW by sex of calf for this particular year is not understood other than possible chance occurrence that might easily happen considering the relatively low association between PCW and growth rate of calf.

The response of calf gain at 365 days of age to PCW is summarized in Table 23. For 1967-68 and 1968-70 male calves, an additional 10 kg PCW was associated with 1.96 and 2.12 kg increased calf weight at 365 days of age. For 1966-67 data, association between 365 day calf weight and PCW was small, negative and inconsistent with the other two periods.

Nelson and Cartwright (1967) reported regression coefficients for weight of dam (100 kg) and PWADG of progeny (kg) as 0.03 and 0.02

(not significant) for Angus and Hereford calves, respectively, postweaning nutrition data was not given. These coefficients are in agreement with coefficients of the present study for 1966-67 male calves but were somewhat lower than that found for 1967-68 and 1968-70 for male calves.

Breed Effect

Breed differences explained from 21.7 to 42.6% additional variance in ADG to weaning (Equations 13a to 18a, Table 22) but only from 0.2 to 13.8% additional variance in PWADG (Equations 13b to 18b, Table 22). As reported in Chapter 3, where cow-calf data were not separated by sex, a large portion of variance in ADG to weaning explained by breed was due to milk yield differences of dams.

It is of interest to note for 1968-70, that breed differences explained very little additional variation in postweaning average daily gain of progeny. Hybrid calves excelled Hereford calves in growth rate up to weaning but they were similar over the postweaning period. This observation is consistent with previous analysis of the HE and HY lines at the University of Alberta beef breeding herd.

Effect of Calf Performance to Weaning on Postweaning Performance

As indicated by the phenotypic correlations given in Table 21, male calves with higher ADG to weaning or male calves heavier at weaning tended to have higher postweaning average daily gain. The correlation coefficients ($r = 0.11$ to 0.27) were low and, in most instances, not significant, $P < .05$. The correlations of preweaning with postweaning performance of female calves were very low.

The partial regression coefficients of PWADG with ADG to weaning

TABLE 20:
Means for cow and calf variables by breed of calf

		1966-67 Data										
		Male calves						Female calves				
		Dam		Calf				Dam		Calf		
Breed of ‡ calf	No.	Age years	PCW	BW	ADG	PW ADG	No.	Age years	PCW	BW	ADG	PW ADG
HExHE	20	5.05	392	34.0	0.78	1.22	15	5.13	425	31.5	0.78	0.69
CHxHE	1	5.00	524	50.8**	0.81	1.09	1	7.00	528	41.7*	0.82	0.65
HYxHE	10	5.20	416	38.8*	0.83	1.28	12	5.42	435	36.5**	0.80	0.71
BSxHE	3	7.00	441	40.4	0.96	1.11	2	7.00	477	40.4*	0.75	0.69
HExAG	6	5.33	397	37.2	0.84	1.10	2	6.00	392	36.7	0.83	0.72
CHxAG	4	7.00	398	40.7*	1.02**	1.21	2	6.50	429	37.6	0.82	0.66
HYxAG	17	5.00	392	33.3	0.93**	1.26	20	5.10	407	34.0	0.87*	0.66
BSxAG	3	8.00	421	40.8	0.98*	1.37	5	7.60	454	35.8	0.98**	0.70
HExHY	5	3.60	399	37.0	0.87	1.03*	8	4.50	403	32.8	0.87	0.69
CHxHY	2	6.00	424	42.9*	0.98	1.13	1	5.00	436	37.2	1.00	0.60
HYxHY	15	3.73	402	35.9	0.92**	1.24	14	3.71	380	33.5	0.91**	0.66
BSxHY	6	5.50	450	42.0*	1.05**	1.38	2	5.00	462	37.4	0.98*	0.60
Total	92						84					
Mean		5.08	406	36.7	0.89	1.22		5.13	417	34.4	0.86	0.68
Standard deviation		2.24	65	5.49	0.15	0.17		2.18	71	4.54	0.11	0.12
		1967-68 Data										
HExHE	34	5.70	430	35.4	0.75	1.40	31	5.70	427	32.4	0.73	0.63
SHxHE	2	2.00	303*	33.3	0.64	1.32						
HYxAG	10	4.30	409	34.7	0.89**	1.32	17	4.50	408	32.6	0.83**	0.67
HYxHY	21	5.00	423	35.0	0.93**	1.47	32	4.70	444	34.0	0.88**	0.65
SHxHY	11	2.00	342	33.9	0.70	1.31						
SHxHEHY	9	2.00	348	34.8	0.76	1.50						
Total	87						80					
Mean		4.43	403	34.9	0.80	1.40		5.00	430	33.0	0.81	0.65
Standard deviation		2.08	65	3.64	0.14	0.16		1.69	56	3.45	0.11	0.12
		1968-70 Data										
HExHE	68	6.40	415	34.9	0.87	1.33	59	6.30	423	32.5	0.80	0.53
HYxHY	92	5.20	406	36.0	1.02**	1.37	66	4.90	420	32.7	0.93**	0.50
Total	160						125					
Mean		5.68	410	33.5	0.96	1.35		5.60	422	32.6	0.87	0.51
Standard deviation		2.32	57	4.49	0.15	0.19		2.59	63	3.84	0.14	0.08

** Significantly different from Hereford controls $P < .01$, $*P < .05$.
‡ Abbreviations given in text.

TABLE 21:
Phenotypic correlation of ADG to weaning and PWADG of calf with several cow-calf variables

Variable‡	1966-67				1967-68				1968-70			
	ADG		PWADG		ADG		PWADG		ADG		PWADG	
	Males N=92	Females N=84	Males N=92	Females N=84	Males N=87	Females N=80	Males N=87	Females N=80	Males N=160	Females N=125	Males N=160	Females N=125
Cow												
Age	.39**	.22*	-.12	-.15	.21*	.05+	:10	-.38**	.12	.27**	0	-.04
PCW	.34**	.37**	-.04	-.20	.29**	.35**	.19	-.22*	.34**	.38**	.03	-.13
Calf												
Age (weaning)	-.25*	.04	.03	.13	-.17	-.08	.06	-.06	.07	.02	-.12	.07
BW	.31**	.29**	.20*	.08	.09	.32**	.33**	.26*	.24**	.45**	.36**	.14
ADG to weaning	-	-	.11	-.10	-	-	.20	.03	-	-	.13	-.08
WW	.83**	.78**	.16	.03	.93**	.85**	.27**	.03	.93**	.89**	.13	-.02

** Significantly different from zero, P < .01, *P < .05.
+ Two year old cows were not included.
‡ PCW - postcalving weight of dam, BW - birth weight of calf, ADG - average daily gain to weaning of calf, WW - weaning weight of calf.

TABLE 22:
Percent total variance (R^2x100), percent additional variance (A.V.) and partial regression coefficients (b) of ADG to weaning and PWADG of male and female calves for 1966-67, 1967-68 and 1968-70 data regressed on BW, PCW and breed holding other specified variables constant

					Dependent variables								
				ADG to weaning (kg)					PWADG (kg)				
Time period	Sex	Last ind. variable entered into equation (L.I.V.)	Other ind. variables entered into equation+	Equation	R^2x100 (%)	A.V. explained by (L.I.V.) (%)	b (L.I.V.) (kg)	$S\bar{b}$ (L.I.V.) (kg)	Equation	R^2x100 (%)	A.V. explained by (L.I.V.) (%)	b (L.I.V.) (kg)	$S\bar{b}$ (L.I.V.)
1966-67	M	BW kg	b,d,e,f,g	1a	46.5	0.6	.0026	.0027	1b	19.4	4.3	.0077*	.0037
	F	BW kg	b,d,e,f,g	2a	45.9	2.4	.0043	.0024	2b	9.9	3.6	.0059	.0034
1967-68	M	BW kg	b,d,e,f,g	3a	46.2	0.4	.0026	.0033	3b	24.9	9.3	.0133**	.0045
	F	BW kg	b,d,e,f,g	4a	51.9	4.5	.0073*	.0028	4b	24.2	9.4	.0114**	.0036
1968-70	M	BW kg	b,c,f,g,i	5a	43.2	0.9	.0038	.0024	5b	21.1	7.3	.0133**	.0035
	F	BW kg	b,c,f,g,i	6a	56.1	5.1	.0099**	.0027	6b	21.1	8.9	.0080**	.0022
1966-67	M	PCW 10(kg)	b,d,e,f,g	7a	46.5	0.6	-.0030	.0032	7b	15.3	0.2	.0022	.0045
	F	PCW 10(kg)	b,d,e,f,g	8a	53.2	9.6	.0078**	.0020	8b	7.9	1.5	-.0039	.0031
1967-68	M	PCW 10(kg)	b,d,e,f,g	9a	46.9	1.1	.0039	.0030	9b	18.4	2.7	.0068	.0042
	F	PCW 10(kg)	b,d,e,f,g	10a	50.2	2.8	.0049*	.0024	10b	15.3	0.5	.0023	.0034
1968-70	M	PCW 10(kg)	b,c,f,g,i	11a	44.0	1.8	.0051*	.0023	11b	15.7	1.9	.0065	.0035
	F	PCW 10(kg)	b,c,f,g,i	12a	51.3	0.2	.0016	.0022	12b	12.4	0.1	.0001	.0002
1966-67	M	Breed	b,f,g	13a	45.9	23.3	--	--	13b	15.0	12.0	--	--
	F	Breed	b,f,g	14a	43.5	33.1	--	--	14b	6.4	3.1	--	--
1967-68	M	Breed	b,f,g	15a	45.8	29.3	--	--	15b	15.6	13.8	--	--
	F	Breed	b,f,g	16a	47.4	42.6	--	--	16b	14.7	0.2	--	--
1968-70	M	Breed	b,f,g,i	17a	42.3	24.1	--	--	17b	13.9	1.0	--	--
	F	Breed	b,f,g,i	18a	51.0	21.7	--	--	18b	12.3	3.1	--	--

+ Code for other independent variables: b - calf age, c - breed of calf, d - breed of sire, e - breed of dam, f - cow age, g - cow age squared, i - year

** Significantly different from zero, $P < .01$, $*P < .05$.

‡ Abbreviations given in Table 2 and text.

TABLE 23:
Expected response of 180 and 365 day calf weight to birth weight of calf and postcalving weight of dam
(derived from Table 22)

Time period	Sex	Increase in calf weight (kg) associated with a 1 kg increase in birth weight		Increase in calf weight (kg) associated with a 10 kg increase in postcalving weight of dam	
		180 days	365 days	180 days	365 days
1966-67	M	1.47	2.89	-.54	-.24
	F	1.77	2.86	1.40	.68
1967-68	M	1.47	4.02	.70	1.96
	F	2.31	4.42	.88	1.31
1968-70	M	1.68	4.14	.92	2.12
	F	2.78	4.27	.29	.31

TABLE 24:

Percent total variance (R^2x100), percent additional variance (A.V.) and partial regression coefficients (b) of PWADG of male and female calves for 1966-67, 1967-68 1968-70 data regressed on ADG to weaning and weaning weight holding other specified variables constant

Time period	Sex	Last ind. variable entered into equation (L.I.V.)	Other ind. variables entered into equation+	Equation	R^2x100 (%)	A.V. explained by (L.I.V.) (%)	b (L.I.V.) (kg)	Sb (kg)
1966-67	M	ADG kg	d,e,f,g	1	15.6	0.6	.1150	.1545
	F	ADG kg	d,e,f,g	2	5.9	0.1	.0559	.1645
1967-68	M	ADG kg	d,e,f,g	3	17.4	1.8	.1994	.1546
	F	ADG kg	d,e,f,g	4	15.7	0.9	.1402	.1548
1968-70	M	ADG kg	d,e,f,g	5	17.2	3.4	.3035*	.1213
	F	ADG kg	d,e,f,g	6	15.5	3.2	.1571*	.0741
1966-67	M	WW 10(kg)	b,d,e,f,g	7	17.1	2.0	.0122	.0086
	F	WW 10(kg)	b,d,e,f,g	8	7.0	0.7	.0064	.0089
1967-68	M	WW 10(kg)	b,d,e,f,g	9	19.4	3.8	.0160	.0084
	F	WW 10(kg)	b,d,e,f,g	10	17.2	2.4	.0123	.0084
1968-70	M	WW 10(kg)	b,c,f,g,i	11	19.3	5.5	.0224**	.0070
	F	WW 10(kg)	b,c,f,g,i	12	16.1	3.8	.0092*	.0040

+ Code for other independent variables: b - calf age; c - breed of calf; d - breed of sire; e - breed of dam; f - cow age; g - cow age squared; i - year

** Significantly different from zero $P < .01$, *$P < .05$.

and weaning weight and percent additional variance of PWADG explained by ADG to weaning and weaning weight are given in Table 24 by sex and year subclasses. For male calves, ADG to weaning explained an additional 0.6 to 3.4% of total variance in PWADG (Equations 1, 3 and 5, Table 24) and weaning weight explained an additional 2.0 to 5.5% of total variance in PWADG (Equation 7, 9, 11, Table 24). Male calves with a 10 kg advantage in weaning weight would be expected to have from a 12 to 14 kg advantage at 365 days of age. Because of the restricted ration and slower growth rate, response of PWADG to ADG to weaning for female calves was somewhat lower than male calves. These results are in general agreement with the literature (Koger and Knox, 1951; Reynolds et al., 1964; Rollins et al., 1962). These workers indicated that the influence of preweaning performance on postweaning performance is dependent upon preweaning conditions. Koger et al. (1951) concluded that growth at different periods are generally positively correlated, however, animals subject to variable external influences such as a variable milk supply of dams may show low or sometimes even a negative correlation to growth over subsequent periods.

V. Evaluation of measurements of cow size as related to progeny performance

A. INTRODUCTION

Emphasis on attaining higher growth rate of beef cattle by selection and breed combination is generally associated with an increase in mature body size. Since net efficiency of a system is a function of the output-input ratio, the economics of larger vs. smaller cows must be related to associated productivity and costs. Fundamental to such analysis is a reliable measure of cow size. Body weight, commonly used as a measure of cow-body size, varies with degree of fleshing or condition, hence does not necessarily reflect physiological size. Where body weight is to be used as a criterion for comparing body size among animals, the population should either be uniform in condition or mathematically adjusted to a common base. The accuracy of either approach is open to question, the chance of a population of animals being uniform in condition is unlikely and measurements of condition, being somewhat subjective, are vulnerable to experimental error.

Unlike body weight, skeletal development is relatively independent of environmental influence and at maturity is essentially a constant reflecting heritable size of skeleton, Davis et al. (1937). Guilbert and Gregory (1952) have indicated the allometric nature of bone development within and between bones. They indicated proportionately faster bone growth in length than width, with circumference growth continuing after length growth has ceased. It has been indicated that length and width of cannon bone at birth are 85 and 55% mature, respectively, wither height is about 50% mature at birth and

skeletal growth has practically ceased at 30 to 40 months, (Brody et al., 1937; Brown et al., 1956; Davis et al., 1937; Eckles, 1915; Guilbert and Gregory, 1952). Height of animal measurements reflect skeletal size; width and body circumference measurements tend to reflect condition, (Brody et al., 1957; Davis et al., 1937; Guilbert and Gregory, 1952; Johansson and Hildeman, 1954; Kress et al., 1969; Yao et al., 1953). Moulten et al. (1921) reported some effect of plane of nutrition on wither height up to 500 days of age, but little effect at maturity.

It may be concluded that body height measurements are good indicators of skeletal size for any particular age of animal, but this does not necessarily imply a high association with muscling. Heart girth and to a lesser extent width measurements are better indicators of live body weight and condition than height measurement and tend to be positively correlated with grade and dressing percentage reflecting the association of these traits with fleshing. However, tissue deposition is not a part-whole relationship and condition implies muscling as well as fatness. Selection for wither height as a criterion of body size may not realize the objective of muscular development at any particular age. This is particularly true in respect to breed differences. McDowell et al. (1959) reported wither height and girth for mature Jersey cows as 119.5 and 159.8 cm, respectively. Guilbert and Gregory (1952) reported wither height and heart girth as 120 and 192 cm, respectively for mature Hereford cows. The height of Jersey and HE cows appears relatively similar, but difference in overall size of cow reflected by heart girth is large.

The objectives of this study were to examine:

(a) the interrelationship of cow-body weight, height at withers and sacrum, heart girth and length,

(b) the relative condition of cows between breed and age groups by body weight-height ratio comparisons,

(c) the association of cow-body size variables with birth weight and performance of progeny, and

(d) the effect of selected cow-body size variables on birth weight and performance of progeny.

B. EXPERIMENTAL

The present investigation involves 1969-70 data from the University of Alberta beef breeding herd. Included in the analyses were 173 cows consisting of 78 Hereford, 18 Angus-Galloway crosses, 51 hybrids, 25 Charolais-Angus crosses and 4 Charolais-Galloway crosses. The hybrids were a synthetic of Charolais, Galloway and Angus breeding. For purpose of analysis, the cow breeds were combined into two categories: Hereford and Angus-Galloway crosses were designated as HEAG and hybrids and other breed crosses were designated as HYC. The progeny were sired by Hereford (HE), hybrid (HY), Shorthorn (SH), and Charolais (CH) sires. The breeding pattern is shown in Table 25. About 60% of calves from HEAG dams were from HE sires and about 85% of calves from HYC dams were from HY sires.

Management and nutrition of the cows and calves were reported in Chapter 4.

Postcalving weight of cow (PCW) and birth weight of calves (BW) were recorded. At weaning, October 3, body weights of cows (WCW) and

TABLE 25:
Number of male and female calves by breed of sire and breed of dam category for 1969 data

	Breed of dam‡					
	Male calves N=87			Female calves N=86		
Breed of sire‡‡	HEAG	HYC	Total	HEAG	HYC	Total
HE	34	1	35	36	0	36
HY	7	37	44	5	29	34
SH	2	0	2	4	9	13
CH	5	1	6	3	0	3
Total	48	39	87	48	38	86

‡‡ HE - Hereford, HY - hybrid, SH - Shorthorn, CH - Charolais.
‡ HEAG - Hereford and Angus-Galloway crosses.
HYC - hybrids and other breed crosses.

weaning weights of calves (WW) were recorded. Although fed separate rations, both male and female calves were placed on feed test for 173 days postweaning. Final weight of the calves were recorded at the end of the feed trial when the calves averaged 338 days of age. Average daily gain of calves from birth to weaning (ADG) and postweaning average daily gain (PWADG) were calculated.

At time of weaning, several cow-body measurements were calculated; height at withers (HW), height at sacrum (HS), heart girth (G) and length (L). Cow height measurements were determined by positioning a level plank above the animal in the chute. The vertical distances from the plank to the withers and sacrum were measured. The vertical distance from the plank to the floor was measured and HW and HS were calculated, respectively, by subtraction of the two measurements. Body length was measured from the spinous process of the second cervical vertebra to the pin bone. Several combined calculations of body measurements were made: the average of HW and HS (H), H x G, H x G x L, PCW/H and WCW/H.

The cow-calf data were analyzed by stepwise multiple regression, the procedure of which has been reported earlier. The data were analyzed collectively for preweaning-calf variables and subclassified by sex for postweaning-calf variables. For further elucidation, the data were also subclassified by breed and age of dam categories. The interrelationships of all body measurements and the relationships of these measurements to calf performance were assessed by a study of simple correlations and multiple regression calculations.

C. RESULTS AND DISCUSSION

Means and standard deviations for several cow and calf variables are given in Table 26. Birth weight of calf differences by breed of dam were small. Calves from HYC dams outperformed calves from HEAG dams for males and females, respectively, in ADG to weaning by 0.15 and 0.12 kg; PWADG by 0.07 and -0.03 kg, and final weight adjusted for calf age by 35 and 12 kilograms. The HYC female calves were 21 kg heavier at weaning, but did not perform quite as well postweaning as those from HEAG dams. Because of higher maintenance requirements, the heavier calves are possibly at a disadvantage when fed a restricted ration. Across breed of dam, male calves excelled female calves by 4.7 kg in birth weight and 0.10 kg in ADG to weaning.

The HEAG and HYC cows averaged 5.8 and 4.7 years of age, respectively. Differences in body weight, heart girth and length measurements were small, however, the HYC group of cows was 5 cm greater in body height than HEAG cows. As indicated by the higher standard deviations, the HYC group tended towards more variation in average height and length than the HEAG group.

In Table 27, a further breakdown of the data is given by age of dam categories: mature, 3 and 4-years, and 2 years. Calves from HYC dams excelled those from HEAG dams in ADG to weaning by 0.17, 0.15 and 0.11 kg, respectively for the 3 age of dam classifications. These differences as previously noted are probably primarily due to differences in milk yield between breed of dam categories. Breed of dam differences within age of dam categories were not large for body weight, length and heart girth. For mature cows, average height at

TABLE 26:
Means and standard deviations for calf performance variables by breed of dam and sex of calf and body size measurements of dams by breed of dam

	Male Calves				Female Calves			
	HEAG	N= 48	HYC	N= 39	HEAG	N= 48	HYC	N= 38
Variable[1]	Mean	S D	Mean	S D	Mean	S D	Mean	S D
Calf								
Birth weight.....kg	35.9	4.84	37.2	2.99	32.0	4.68	31.5	4.70
Age-weaning....days	161	14	168	10	164	16	168	15
ADG - weaning....kg	0.85	0.14	1.00	0.13	0.77	0.14	0.89	0.14
Weaning weight...kg	173	27	204	23	159	28	180	29
PW ADG...........kg	1.37	0.20	1.44	0.17	0.55	0.07	0.52	0.09
Final weight.....kg	374	46	416	28	241	29	257	34
	HEAG	N= 96	HYC	N= 77				
	Mean	S D	Mean	S D				
Cow								
Age..........years	5.9	2.84	4.7	2.30				
PCW.............kg	397	63	389	62				
WCW.............kg	494	67	493	70				
HW..............cm	117	3.81	121	4.5				
HS..............cm	122	3.45	126	4.5				
G...............cm	178	9.10	177	8.82				
L...............cm	143	6.12	144	7.82				
H...............cm	119	3.44	124	4.31				

[1] ADG - Average daily gain to weaning; PWADG - postweaning average daily gain; PCW - postcalving weight of cow; WCW - weight of cow after weaning her calf; HW - height at wither; HS - height at sacrum; H - average of wither-sacral height; G - heart girth and L - length of cow.

TABLE 27:
Means and standard deviations for cow-body-size variables and preweaning performance variables of progeny by breed and age of cow

Variable[1]	Mature dams				3 and 4-year old dams				2-year old dams			
	HEAG	N= 62	HYC	N= 36	HEAG	N= 18	HYC	N= 27	HEAG	N= 16	HYC	N= 14
	Mean	S D	Mean	S D	Mean	S D	Mean	S D	Mean	S D	Mean	S D
Calf												
Birth Weight....kg	36.0	4.42	36.5	3.56	32.6	3.99	34.5	3.93	27.6	2.24	28.7	4.89
Age-weaning...days	162	14	169	12	157	19	164	14	174	8	175	6
ADG - weaning...kg	0.86	0.13	1.03	0.09	0.77	0.11	0.92	0.11	0.65	0.10	0.76	0.11
Weaning weight..kg	176	27	211	21	154	23	185	21	141	15	161	26
Cow												
Age..........years	7.47	2.08	6.94	1.69	3.50	0.51	3.33	0.48	--	--	--	--
PCW............kg	429	45	438	48	357	44	355	42	314	33	332	30
WCW............kg	528	50	550	46	457	36	476	46	401	34	408	34
EW.............cm	118	2.90	123	4.10	117	3.33	121	3.98	112	3.32	117	3.83
HS.............cm	123	3.30	127	4.69	121	3.43	125	4.05	119	3.40	123	4.12
G..............cm	182	6.24	184	5.46	175	7.76	174	5.47	165	6.43	166	5.34
L..............cm	146	4.62	149	5.62	141	4.42	142	4.76	135	5.68	134	5.31
H..............cm	120	2.73	125	4.14	119	3.28	123	3.83	115	3.26	120	3.75

[1] Abbreviations given in Table 2 and text.

sacrum was 123 cm for HEAG and 127 cm for the HYC group. Klosterman et al. (1968) reported average height at hooks for 2 groups of mature Hereford cows as 120 and 121 cm and for 2 groups of mature Charolais cows as 132 and 142 centimeters. As indicated by the relatively small differences of body-size variables and their standard deviations between breed groups, it may be concluded that variation of cow size within the herd under study was not high.

Body measurements of cows within both breed groups increased with age. Differences in body measurements between the 2 year old and 3 and 4 year old cows were 3 to 4 cm for height at withers, 7 to 8 cm for length of body and 8 to 10 cm for heart girth. Differences in body measurements between the 3 and 4 year old and mature cows were 1 to 2 cm for height at withers, 5 to 7 cm for body length and 7 to 10 cm for heart girth. These results are in agreement with Guilbert and Gregory (1952) for height measurements of Hereford cattle, however they reported higher heart girth measurements, 180 cm for 2 year old and 192 cm for mature cows vs. 165 and 182 cm for the present study.

Body weight-height ratio

Working with mature 3/4 Charolais and Hereford cows, Klosterman et al. (1968) suggested body weight-height ratio as being a reasonably reliable measure of body condition. They found highly significant correlations of 0.89 and 0.51 for body weight-height ratios, respectively with condition score and ultrasonic measurement of fat thickness. Considering the wide divergence of body size, these workers reported a remarkable similarity between weight-height ratios between the two breeds, 4.3 for Herefords and 4.6 for Charolais when in fleshy

condition and 3.6 for Hereford and 3.5 for Charolais when in relatively thin condition. They suggested a weight-height ratio of 4 as indicative of average condition. Body weight-height ratios for the present study are given in Table 28. Weight gain by cows over summer was reflected by the relatively high WCW-height ratios compared to the lower PCW-height ratios. Since body measurements were taken in the fall, the PCW-height ratios would have a slight downward bias for younger cows that had not completed skeletal growth at time of the PCW recording. Compared to HYC cows, HEAG cows across age groups had a higher PCW/H, 3.32 vs. 3.15, significant $P < .05$; and a higher WCW/H, 4.13 vs. 4.02, not significant. This suggests that HYC cows tended to catch up to the HEAG cows in condition over summer. For the mature and 3 and 4-year age groups, HEAG vs. HYC cows had slightly higher PCW-height ratios, but no difference was indicated in WCW-height ratios. For the 2-year age group, HEAG vs. HYC cows had a lower PCW-height ratio but slightly higher WCW-height ratio. A weight-height ratio of 4 suggested by Klosterman et al. (1968) as representing average condition tends to agree with the findings of the present study for mature cows. For younger cows both PCW-height and WCW-height ratios were somewhat lower than for mature cows. This suggests that either younger cows were in a thinner condition than mature cows or that average body condition may be associated with a lower weight-height ratio for immature cows. It is believed that the immature cows were probably not as well fleshed as mature cows both after calving and at time of weaning their calves.

TABLE 28:
Body weight-height ratios for beef cows by breed and age categories

Dams		N	PCW/H	S D	WCW/H	S D	PCW/HW	WCW/HW	PCW/HS	WCW/HS[‡]
Mature	HEAG	62	3.56	.35	4.39	.37	3.63	4.47	3.49	4.31
Mature	HYC	36	3.49	.34	4.39	.31	3.56	4.47	3.42	4.31
3 & 4-yr.	HEAG	18	3.01	.32	3.85	.23	3.07	3.93	2.95	3.77
3 & 4-yr.	HYC	27	2.88	.31	3.86	.32	2.94	3.94	2.82	3.78
2-yr.	HEAG	16	2.72	.23	3.47	.22	2.80	3.58	2.64	3.36
2-yr.	HYC	14	2.76	.20	3.39	.20	2.83	3.49	2.69	3.29
All	HEAG	96	3.32	.47	4.13	.48				
All	HYC	77	3.15	.45	4.02	.47				

[‡] Abbreviations given in Table 2 and text.

Intercorrelations of body size variables

Intercorrelations of cow-body-size variables are given in Table 29. Cow weight was more highly correlated with heart girth than either height or body length. Correlations between PCW and WCW with respective weight-height ratios were very high (r = 0.98 and 0.97). Of all variables studied, height of cow appeared to be least associated with body weight, r = 0.54 and 0.62 for H with PCW and WCW, respectively. Correlations of PCW with body measurements were generally higher for 2-year-old cows than other age groups, however, when cows were in better condition, correlations of WCW with body measurements across cow age groups were similar. Interrelationships of body-size variables were relatively similar for the two breed groups studied. The HYC dams compared to HEAG dams had a lower correlation between body weight and height, r = 0.61 vs. 0.70, a lower correlation between body length and height, r = 0.59 vs. 0.69, but a higher correlation between body height and heart girth 0.68 vs. 0.61 (not shown in tables). The above relationships of cow body weight with body measurements are in general agreement with the literature. Brody et al. (1923) reported heart girth to be highly associated with body condition. Johansson and Hildeman (1954) reported correlations of heart girth with live body weight of cattle across age and condition categories as 0.837 and 0.857. They cite Wanderstock and Salisbury (1946) as reporting correlations of 0.73, 0.93 and 0.80 for live weight of beef and dairy cattle, respectively with wither height, heart girth and body length. Gregory (1933) reported a correlation of 0.38 between live weight and wither height.

Intercorrelations of cow-body-size measurements were not particularly high, 0.53 for H and G, 0.63 for H and L and 0.72 for G

TABLE 29:
Intercorrelations of several cow-body-size variables for 173 cows across age and breed categories

‡	WCW	H	G	L	HxG	HxGxL	PCW/H	WCW/H
PCW	.87	.54	.78	.73	.77	.80	.98	.84
WCW		.62	.90	.80	.89	.90	.81	.97
H			.53	.63	.83	.80	.35	.42
G				.72	.91	.88	.73	.88
L					.77	.91	.65	.73
HxG						.97	.65	.78
HxGxL							.69	.80
PCW/H								.84

‡ All coefficients are highly significant at $P < .01$.
Abbreviations given in Table 2 and text.

and body length (Table 29). Brown et al. (1956) reported correlations of wither height and body length as 0.56 for older cattle. Kidwell (1955) with fat Hereford steers reported correlations of 0.49 for wither height and heart girth, 0.53 for wither height and body length, and 0.47 for body length and heart girth. Kohli et al. (1951) reported correlations of wither height with body length as 0.22 to 0.38.

Correlations of calf performance with body measurements of dam

As indicated in Table 30, when considered across breed and age of dam, birth weight and ADG of calf were positively correlated with body weight and skeletal measurements of dam. This would be as expected, as cows mature they become larger in skeletal size, heavier in body weight, produce heavier calves at birth and yield more milk. When the data were considered within breed and age of dam categories, birth weights of calves from HEAG dams were positively correlated with cow-size variables, however, for the mature and 2-year old dam categories for the HYC group, birth weight of calves was negatively correlated with cow-size variables, (not significant). Yao et al. (1953) and Kohli et al. (1951) working with Shorthorn steers, found positive correlations between birth weight and body length or height measurements but negative correlations with body width measurements.

Within cow-age and breed categories correlations of ADG of calves to weaning with cow-body-size variables were low and in most instances not significant. For the HEAG group, with exception of H, (r = 0.01) the correlations of ADG with cow-body-size variables were negative for the mature category and positive for the other age groups of dams. For the HYC group, ADG was positively correlated with

cow-size variables in the mature and 3 and 4-year old groups but negatively correlated in the 2-year old group of cows (3 and 4-year old and 2-year old group not shown in Table 30).

Correlations of PWADG with cow-size variables across breed and age of dam, with exception of PCW, r = -0.05, and G, r = -0.09, were low and positive for male calves and negative for female calves. Within breed and across age of dam, correlations between PWADG of male calves and cow-size variables were low and positive for HEAG dams and negative for HYC dams. In most instances, the coefficients were not significant, $P < .05$ (Table 30).

Within the population studied, these results indicated the influence of cow size on growth rate of progeny to be low, fluctuating from positive to negative.

Correlations of birth weight and preweaning performance with PWADG are given in Table 31. When considered across breed of dam, birth weight and ADG to weaning for male calves were positively correlated with PWADG, r = 0.26 and 0.19, respectively. The correlations of PWADG for male calves with birth weight and ADG to weaning were respectively, 0.41 (significant $P < .01$) and 0.29 (significant $P < .05$) for HEAG dams and -0.17 and -0.19 for HYC dams. Calves from HYC dams with higher preweaning gains tended to have lower postweaning gains.

With the HYC group, the negative relationship of PWADG for male calves with birth weight and cow-body-size variables is to be expected since these variables were positively associated with ADG to weaning but ADG was negatively associated with postweaning average daily gain. This suggests that calves from HYC dams with lower preweaning gains realized compensatory gain over the postweaning feed period.

TABLE 30:
Correlations of calf performance with several body-size variables of dam

Calf variables‡	N	Cow body size variables‡ PCW	WCW	H	G	L	HxG	HxGxL
ACROSS BREED AND AGE OF DAM								
Birth weight, males & females	173	.43**	.56**	.35**	.52**	.50**	.51**	.53**
ADG to weaning, males & females	173	.34**	.45**	.50**	.58**	.42**	.49**	.49**
PW ADG, males	87	-.05	.05	.16	-.09	.06	.03	.04
PW ADG, females	86	-.17	-.18	-.29**	-.21*	-.30	-.27*	-.30**
WITHIN BREED OF DAM (MATURE COWS)								
Birth weight, males & females								
HEAG	62	.08	.33*	.20	.23	.39**	.26*	.34**
HYC	36	-.28	-.06	-.05	-.10	-.18	-.08	-.13
ADG to weaning, males & females								
HEAG	62	-.32*	-.14	.01	-.21	-.16	-.15	-.13
HYC	36	.16	.31	.24	.19	.16	.25	.24
WITHIN BREED, ACROSS AGE OF DAM								
PW ADG, males								
HEAG	48	.06	.18	.25	.06	.23	.15	.19
HYC	39	-.20	-.20	-.11	-.31*	-.25	-.24	-.25
PW ADG, females								
HEAG	48	-.12	-.10	-.08	-.13	-.17	-.12	-.15
HYC	38	-.25	-.29	-.45**	-.34*	-.44**	-.41*	-.44**

** Significantly different from zero at $P < .01$; $*P < .05$.
‡ Abbreviations given in Table 2 and text.

TABLE 31:
Correlations of birth weight and ADG to weaning and weaning weight with PW ADG of calf across breed and age of dam and within breed and across age of dam

Ɨ	No.	Birth weight	ADG to weaning	Weaning weight
ACROSS BREED AND AGE OF DAM				
PW ADG, males	87	.26*	.19	.16
PW ADG, females	86	.17	-.10	.01
WITHIN BREED ACROSS AGE OF DAM				
PW ADG, males				
HEAG	48	.41**	.29*	.26
HYC	39	-.17	-.19	-.25
PW ADG, females				
HEAG	48	.08	-.11	-.02
HYC	38	.24	.02	.15

** Significantly different from zero, $P < .01$, * $P < .05$.
Ɨ Abbreviations given in text.

Compensatory growth has been reported when calves have been introduced to a relatively low postweaning nutritional plane for some time before being placed on full feed (Alexander and Beattie, 1968; Bohman and Clark, 1956). Koger and Knox (1951) concluded that "under constant environment there is a positive relationship between gains made at different periods." They suggested, however, that "this relationship can be obscured or reversed by variable conditions." Stuedemann et al. (1968) reported no indication of compensatory gain when 5 groups of calves were fed on levels of nutrition ranging from very restricted to very high up to 8 months of age and then placed on full feed.

The effect of cow-body size on preweaning performance of progeny

Postcalving weight (PCW) and average wither-sacral height (H) of cow were selected as measurements of cow-body size for study of the effect of cow-body size on calf performance. Since weight-height ratios approached unity in correlation with body weight these variables were not included in the regression equations. The inclusion of either H x G or H x G x L explained little additional variance of calf performance above body weight of dam alone.

Results of regressing ADG to weaning and weaning weight on body weight and height of dam and birth weight of calf for all cows, HEAG cows and HYC cows are given in Table 32. Considering the data across breed, Equations 1(a) to 10(a), breed of sire and dam, age and age squared of dam and sex and weaning age of calf were held constant. In Equations 1(b) to 10(b) and 1(c) to 10(c) where the data was analyzed within breed of dam category, cow age and age squared and weaning age

and sex of calf were held constant. The equations suggest that 10 kg additional PCW of dam would result in approximately 0.7 kg additional weight of calf at weaning, which is in agreement with the analysis of Chapter 3. The percent of additional variance in ADG of calf to weaning explained by PCW ranged from 0.4 to 1.1, Equation 1(a), (b) and (c). Postcalving weight and height of dam were essentially interchangeable as to effect on ADG to weaning for calves of HYC dams, body weight alone would have been a satisfactory measure of body size, Equations 1(c), 2(c) and 3(c). However, with HEAG dams, Equations 1(b), 2(b) and 3(b), PCW only accounted for 0.4% additional variance in ADG to weaning, height of dam accounted for 2.9% and when PCW was held constant height accounted for 2.6 percent. Compared to HYC dams, the HEAG dams were probably in better condition after calving as previously suggested by the higher PCW/H ratios. This may explain the higher response of ADG to height vs. PCW as a measurement of body size in HEAG dams.

As indicated in Equations 7(a), (b) and (c) a 1 cm increase in height of dam would be associated with an increase in weaning weight of progeny of 0.97, 1.82 and 0.63 kg, respectively for all cows across breed, HEAG, and HYC cows.

The influence of birth weight on preweaning performance appeared to be relatively independent of cow-body size, Equations 4(a), (b), (c), 5(a), (b), (c), 9(a), (b), (c) and 10(a), (b), (c), Table 32. When PCW and height of dam were held constant, the percent additional variance of ADG to weaning explained by birth weight was reduced by 50% with the HEAG group and remained the same with the HYC group, Equations 4(b), 5(b), 4(c) and 5(c). An increase of 1 kg in birth

weight of calf resulted in increases of 1.79, 2.06 and 2.16 kg in weaning weight for calves from all cows, HEAG cows and HYC cows, respectively, Equations 9(a), (b) and (c). The coefficient for all cows was somewhat lower than that for the within breed groups because breed of sire as well as breed of dam were held constant in this equation. These results agree with the analysis given in Chapter 3.

The effect of PCW and height of dam on birth weight is shown in Equations 11(a) to 13(c) Table 32 for all cows, HEAG and HYC cows. As shown in Equations 11(c), 12(c) and 13(c), cow size explained very little additional variance in birth weight of calves from HYC dams, the partial regression coefficient for birth weight on height of dam was negative but not significant. With HEAG dams, PCW explained 4.9% of additional variance in birth weight and height of dams explained 8%, Equations 11(b) and 12(b). When PCW was held constant, height of dam explained an additional 3.8% of the variance in birth weight, Equation 13(b). For the HEAG calves, a 10 kg increase in PCW resulted in a 0.3 kg increase in birth weight and a 1 cm increase in height of dam resulted in a 0.5 kg increase in birth weight of calf, Equations 11(b) and 12(b).

<u>The effect of cow-body size on postweaning performance of progeny</u>

The effect of cow size and birth weight on PWADG for male and female calves across and within breed of dam are shown in Table 33. Age and age squared of dam and age of calf were held constant across all equations and breed of dam and breed of sire were held constant for those equations calculated across breed category. As indicated in Equation 1(a), 2(a) and 3(a) the effect of either PCW or height

Table 32

Percent total variance (R^2x100), percent additional variance (A.V.), and partial regression coefficients (b) of several calf performance variables regressed on body weight and height of dam and birth weight of calf.

Last ind. variable to enter equation (L.I.V.)‡		Other ind. variables entered into equation +	Dependent variable	All cows N = 173 Equation	All cows R^2x100 (%)	All cows A.V. explained by L.I.V. (%)	All cows b L.I.V. (kg.)	HEAG cows N = 96 Equation	HEAG R^2x100 (%)	HEAG A.V. explained by L.I.V. (%)	HEAG b L.I.V. (kg.)	HYC cows N = 77 Equation	HYC R^2x100 (%)	HYC A.V. explained by L.I.V. (%)	HYC b L.I.V. (kg.)
PCW	kg	a,b,c,d	ADG to weaning	1a	61.4	0.5	.00029	1b	39.9	0.4	.00025	1c	57.2	1.1	.00036
H	cm	a,b,c,d		2a	61.8	1.0	.00488*	2b	42.4	2.9	.00818*	2c	57.3	1.2	.00396
H	cm	a,b,c,d,e		3a	61.9	0.5	.00417	3b	42.5	2.6	.00975*	3c	57.6	0.3	.00265
BW	kg	a,b,c,d		4a	62.0	1.1	.00488*	4b	42.6	3.0	.00698*	4c	59.0	2.8	.00706*
BW	kg	a,b,c,d,e,f		5a	62.7	0.8	.00413	5b	44.0	1.5	.00534	5c	60.5	2.9	.00720*
PCW	kg	a,b,c,d	Weaning weight	6a	70.2	0.8	.07187*	6b	51.7	0.9	.07231	6c	65.6	0.9	.06636
H	cm	a,b,c,d		7a	70.4	1.0	.97122*	7b	54.1	3.3	1.82135*	7c	65.4	0.7	.62781
H	cm	a,b,c,d,e		8a	70.5	0.4	.70651	8b	54.1	2.4	1.82404*	8c	65.7	0.1	.33197
BW	kg	a,b,c,d		9a	73.2	3.9	1.78876**	9b	57.9	7.1	2.06412**	9c	71.4	6.7	2.15932**
BW	kg	a,b,c,d,e,f		10a	73.7	3.2	1.65436**	10b	58.7	4.5	1.81410**	10c	72.5	6.7	2.18169**
PCW	kg	a,b,c,d	Birth weight	11a	53.6	1.7	.01611*	11b	53.2	4.9	.03017**	11c	49.3	0.1	.00416
H	cm	a,b,c,d		12a	53.3	1.5	.18301*	12b	56.3	8.0	.50536**	12c	49.3	0.2	-.04838
H	cm	a,b,c,d,e		13a	53.9	0.4	.11002	13b	57.0	3.8	.41015**	13c	49.8	0.6	-.11436

** Significantly different from zero, $P < .01$, *$P < .05$.
+ Breed of sire and dam (a) included only for those equations for "all cows"
‡ Abbreviations given in Table 2 and text.

Code: a - breed of sire and dam
b - age and age squared of dam
c - age of calf to weaning
d - sex of calf
e - post calving weight of dam (PCW)
f - average wither-sacral height of dam (H)

of dam on PWADG was small explaining 0.4 to 1.0% of additional variance. However, as shown in Equations 1(b), 2(b), 3(b), 1(c), 2(c) and 3(c), there was a noticeable breed difference in response of PWADG to PCW and height of dam. This difference was also reflected in final weight of calf. For HEAG cows, a 10 kg increase in PCW resulted in a 0.47 kg decrease in final weight of calf, whereas a 1 cm increase in height of dam resulted in a 3.73 kg increase in final weight (Equations 6(b) and 7(b)). When PCW was included as a constant variable, a 1 cm increase in height of dam resulted in a 6.61 kg increase in final weight of calf (significant $P < .05$) and explained an additional 10.2% of total variance in final weight (Equation 8(b)). This relationship was reversed for male calves from HYC dams where a 10 kg increase in PCW resulted in a 1.91 kg increase in final weight of calf and a 1 cm increase in height of dam resulted in a 0.82 kg increase in final weight (Equations 6(c) and 7(c)). When PCW was included as a constant variable, a 1 cm increase in height of dam resulted in a 0.34 kg decrease in final weight of calf (Equation 8(c)). The response of PWADG of female calves, on a restricted ration, to PCW and height of dam is shown in Equations 11(a), (b), (c) to 13(a), (b) and (c). The coefficients were small and positive for the HEAG group and negative for the HYC group. For the HYC group, a 1 cm increase in height of dam was associated with a -0.008 kg decrease in PWADG of female calf (significant $P < .05$, Equation 12(c)). When PCW was held constant a 1 cm increase in height of dam resulted in a decrease of 0.01266 kg in PWADG (significant $P < .01$, Equation 13(c)). These results possibly reflect the tendency reported earlier for the heavier female HYC calves at weaning to have a slightly lower postweaning performance.

As indicated in Equations 4(b) and 5(b), calves from HEAG dams that were heavier at birth tended to have higher postweaning gains. Birth weight accounted for 10.7% of the variance in PWADG (Equation 4(b), or 13.2% of the variance in final weight of male calves from HEAG dams (Equation 9(b)). The influence of birth weight on PWADG was relatively independent of cow size as indicated in Equation 5(b). The effect of birth weight for male calves from HYC dams on PWADG was low and negative (Equations 4(c) and 5(c)).

For female calves, the effect of birth weight on PWADG was similar to that of male calves for the HEAG group, however, for the HYC group the effect was considerably higher accounting for 21.1% of the variance in PWADG and 39.7% of the variance in final weight (Equations 14(c) and 19(c). For female calves, a 1 kg increase in birth weight resulted in a 3.6 and 5.1 kg increase in final weight of calf, respectively for HEAG and HYC dams. For HYC dams, the total variance of final weight of calf explained by birth weight, cow age and calf age was 10.4 and 74.6% respectively for male and female calves (Equations 9(c) and 19(c). The variation between animals on a restricted dietary intake is considerably less than animals on full feed, which probably accounts for the higher proportions of explained variance attributable to birth weight for female calves.

The difference in response of PWADG of progeny to height and body weight as measurements of cow size for the two breed categories indicates that weight and height combined would be more consistent than either variable alone. However, the effect of either weight or height of dam on calf performance was low and fluctuating.

Table 33
Percent total variance (R^2x100), percent additional variance (A.V.) and partial regression coefficients (b) of PW ADG of male and female calves regressed on body weight and height of dam and birth weight of calf

Last ind. variable to enter equation (L.I.V.) ‡	Other Ind. variables entered into equation +	Dependent variable	Equation	R^2x100 (%)	A.V. explained by L.I.V. (%)	b L.I.V. (kg)	Equation	R^2x100 (%)	A.V. explained by L.I.V (%)	b L.I.V. (kg.)	Equation	R^2x100 (%)	A.V. explained by L.I.V. (%)	b L.I.V. (kg.)
			MALE CALVES											
			All cows N = 87				HEAG cows N = 48				HYC cows N = 39			
PCW kg	a,b,c	PW ADG	1a	14.1	0.1	-.00012	1b	9.7	2.4	-.00077	1c	23.0	3.3	.00081
H cm	a,b,c		2a	14.5	0.4	.00356	2b	10.2	3.0	.01253	2c	19.7	0.0	-.00045
H cm	a,b,c,e		3a	15.1	1.0	.00661	3b	21.1	11.5	.03097*	3c	25.4	2.4	-.00770
BW kg	a,b,c		4a	18.5	4.5	.01275*	4b	17.9	10.7	.01700*	4c	19.7	0.0	-.00037
BW kg	a,b,c,e,f		5a	19.8	4.7	.01392*	5b	29.4	8.3	.01590*	5c	25.6	0.2	-.00296
PCW kg	a,b,c	Final weight	6a	47.1	0.5	.07487	6b	20.6	0.2	-.04722	6c	16.3	6.9	.19099
H cm	a,b,c		7a	48.3	1.6	1.58525	7b	25.6	5.2	3.73002	7c	11.1	1.6	.81682
H cm	a,b,c,e		8a	48.3	1.1	1.64472	8b	30.8	10.2	6.61300*	8c	16.5	0.2	-.34281
BW kg	a,b,c		9a	49.0	2.3	2.11976	9b	33.6	13.2	4.25373**	9c	10.4	1.0	-1.10363
BW kg	a,b,c,e,f		10a	50.3	2.1	2.01887	10b	40.1	9.3	3.80220*	10c	17.9	1.4	-1.34776
			FEMALE CALVES											
			All cows N = 86				HEAG cows N = 48				HYC cows N = 38			
PCW kg	a,b,c	PW ADG	11a	27.1	0.0	.00002	11b	8.4	2.4	.00035	11c	15.2	0	-.00001
H cm	a,b,c		12a	28.7	1.5	-.00341	12b	6.9	0.9	.00247	12c	25.6	10.5	-.00826*
H cm	a,b,c,e		13a	29.3	2.2	-.00461	13b	8.6	0.1	.00095	13c	31.0	15.8	-.01266**
BW kg	a,b,c		14a	37.7	10.5	.00747**	14b	18.3	12.3	.00788*	14c	36.3	21.1	.00981**
BW kg	a,b,c,e,f		15a	41.7	12.4	.00832**	15b	19.0	10.4	.00836*	15c	50.8	19.8	.00953**
PCW kg	a,b,c	Final weight	16a	51.3	0.1	.02863	16b	49.4	2.0	.12379	16c	35.0	0.1	.02228
H cm	a,b,c		17a	51.3	0.0	.23274	17b	51.8	4.4	2.14250	17c	35.9	1.0	-.95827
H cm	a,b,c,e		18a	51.3	0.0	.07354	18b	52.2	2.8	1.86775	18c	37.1	2.1	-1.74992
BW kg	a,b,c		19a	72.1	20.9	4.11137**	19b	64.6	17.2	3.58479**	19c	74.6	39.7	5.09255**
BW kg	a,b,c,e,f		20a	72.7	21.3	4.26035**	20b	64.8	12.6	3.57995**	20c	76.1	38.9	5.05593**

** Significantly different from zero, P<.01, *P<.05.
+ Breed of dam and sire (a) included only for those equations for "all cows."
‡ Abbreviations given in Table 2 and text.
Code: a - breed of sire and dam
b - age and age squared of dam
c - age of calf to end of feed trial
e - postcalving weight of dam (PCW)
f - average wither-sacral height of dam (H)

VI. A marginal economic analysis of the influences of body size and milk yield of beef cows

A. INTRODUCTION

A major emphasis in respect to beef breeding systems has been on increased rate of growth. Selection, heterosis and breed complementarity have been utilized either independently or jointly as means towards the achievement of this objective. An increase of both milk production and mature size of dam is frequently associated with increased growth rate of progeny. This is particularly true where large breeds of high milk yielding potential are incorporated with the traditional beef breeds. Beef breeding systems are frequently compared with respect to gross productivity rather than net efficiency. However, additional animal output is always associated with additional feed input, hence any animal production system should be assessed on net rather than gross efficiency. Since feed costs constitute about 60% of total annual costs of a cow-calf enterprise (Hackett, 1967), relating feed input to product output should be useful in making meaningful comparisons between breeding systems.

The physical relationships of body-size variables and milk production of dam with preweaning and postweaning performance of calf for the University of Alberta beef breeding herd have been examined. The parameters established for predicting response of calf performance to postcalving weight and milk yield of dam will be used for this study.

The objectives of this study were:

(a) to compare a 450 kg cow with a 500 kg cow in respect to the marginal product of calf at weaning and at one year of age and to

determine the associated inputs of metabolizable energy and cost of marginal product of calf, and

(b) to estimate the marginal input and cost of metabolizable energy associated with the marginal product of calf at weaning as realized from an increase of 1 kg in daily milk production of dam.

The term marginal is used frequently in economics and has the same meaning as added (Heady and Jensen, 1960). For example, marginal product at weaning as associated with cow size indicates the amount added to weaning weight of progeny by a specified increment in body size of dam.

B. EXPERIMENTAL

Biologically, efficiency of beef production can best be described by the ratio of net energy retention to energy input. However, net energy retention per unit weight of product increases with the proportion of fat synthesized, hence is difficult to relate to value.

For purposes of this study, feed input was expressed as megacalories (Mcal) of metabolizable energy and output as kilograms (kg) of live body weight.

To establish models for the marginal analysis, it was necessary to decide how the energy requirement for maintenance of an animal varies with changes in body weight. The energy requirement of an animal for maintenance by definition is the amount of energy required to maintain zero energy balance and includes the amount of energy required to satisfy the energy expenditure of basal metabolism, heat increment of feeding, activity and temperature stress. Basal metabolism refers to the energy expenditure of an animal existing in a

resting-post-absorptive state and in a thermo-neutral environment. Since a complete resting state is impossible to achieve with large animals, fasting metabolism is generally used in preference to basal metabolism (Blaxter, 1967). Rubner (1883) as cited by Blaxter (1967) developed the theory that basal metabolism varied proportionately to surface area rather than body weight. Difficulties in measuring surface area led Brody (1945) to equate basal metabolism with a power of body weight. He found that basal metabolism across species approximated 70.5 kilocalories per kilogram body weight to the power of 0.73 (70.5 kcal/kg$W^{0.73}$). Kleiber (1947) as cited by Blaxter (1967) found that basal metabolism of homeotherms varied with body weight to the power of 0.75, which is the constant used by NRC (1970). It has been reported that feed intake for maintenance of beef cattle within a breed may vary proportionately to body weight rather than metabolic size ($W^{0.73}$ or $W^{0.75}$), (Stonaker, et al., 1952; Taylor and Young, 1968). To be consistent with common usage, $W^{0.75}$ was adopted as the unit of reference for metabolic size in this investigation.

Expressing metabolizable energy for maintenance (ME_m) as being proportional to a positive fractional exponent of body weight ($W^{0.75}$) indicates that ME_m will increase at a decreasing rate as body weight increases. Hence, the marginal ME_m must be calculated by difference in ME_m for the two animals to be compared rather than determining ME_m on the basis of marginal body weight.

The University of Alberta beef breeding herd was used as a reference point for deciding on cow and calf weights for purposes of comparison. For the marginal analysis, cow body weights of 450 and 500 kg were chosen. It was assumed that the calves from 450 kg cows

have a birth weight of 35 kg, weigh 200 kg at weaning and 400 kg at 1 year of age. Thus, accumulated gain to weaning would be 165 kg and the average weight to be maintained from birth to weaning would be 165/2 + 35 = 118 kilograms. Similarly, the average weight to be maintained from birth to weaning can be calculated for calves from 500 kg dams.

From weaning to slaughter, the average weight to be maintained would simply be weaning weight + $\frac{\text{gain}}{2}$. It was assumed that the calves were weaned at 180 days and fed ad libitum on a predominantly concentrate ration from weaning to slaughter at 365 days of age. The ration of the cows was assumed to be pasture for 180 days and hay for 185 days.

The marginal analysis relating additional feed input to additional product is illustrated in Figures 3, 4 and 5.

A solution to the models as presented required the following information:

1. The influence of cow-body size on growth rate of progeny to weaning and 1 year of age,
2. The influence of milk yield of dam on growth rate of calf to weaning,
3. ME_m for a beef cow, 180 days pasture, 185 days hay,
4. ME_m for a beef calf, 180 days suckling, 185 days finishing ration,
5. Metabolizable energy for gain (ME_G) for a beef calf, 180 days suckling, 185 days finishing ration,
6. ME requirement for milk production, 180 days pasture,
7. Estimates of associated costs.

Figure 3: Method for calculation of ME and associated costs of the marginal product of calf at weaning as associated with size of dam. (ME_m calculated for 24 hours, ME expressed in Mcal).

$$ME_m \boxed{(500\ kg)^{0.75}} - ME_m \boxed{(450\ kg)^{0.75}} = \boxed{mg\ ME_m D} \quad (1)$$

[(1) x (180 days) x (Cost/Mcal ME, pasture)] + [(1) x (185 days) x (Cost/Mcal ME, hay)] = Cost $\boxed{mg\ ME_m D}$ (2)

$$\boxed{W\ wt\ P,\ 500\ kg\ D} - \boxed{W\ wt\ P,\ 450\ kg\ D} = \boxed{mg\ p_w} \quad (3)$$

$$ME_m \left(\boxed{B\ wt\ P} + \boxed{\frac{GWP}{2}} \right)^{0.75} = \boxed{ME_m P_w} \quad (4)$$

$$\boxed{ME_m P_w\ 500\ kg\ D} - \boxed{ME_m P_w\ 450\ kg\ D} + \boxed{ME_G\ mg\ p_w} = \boxed{ME\ mg\ p_w} \quad (5)$$

(5) x (180 days) x (Cost/Mcal ME, milk from dam through pasture)= Cost of $\boxed{mg\ pW}$ for maintenance and gain (6)

(2) + (6) = Total cost $\boxed{mg\ p\ W}$ (7)

$$\frac{(7)}{\boxed{mg\ p\ W}\ kg} = \text{Cost/kg}\ \boxed{mg\ p\ W} \quad (8)$$

DEFINITIONS OF ABBREVIATIONS:

ME - metabolizable energy

ME_m - metabolizable energy for maintenance/kg $^{0.75}$/24 hours

$\boxed{mg\ ME_m D}$ - marginal ME_m for dams

$\boxed{W\ wt\ P,\ 500\ kg\ D}$ - weaning weight of progeny for a 500 kg dam

$\boxed{W\ wt\ P,\ 450\ kg\ D}$ - weaning weight of progeny for a 450 kg dam

$\boxed{mg\ p_w}$ - marginal product at weaning

$\boxed{B\ wt\ P}$ - birth weight of progeny

$\boxed{\frac{GWP}{2}}$ - (gain of progeny to weaning ÷ 2

$\boxed{ME_m P_w}$ - ME_m for progeny from birth to weaning

$\boxed{ME_m P_w\ 500\ kg\ D}$ - ME_m from birth to weaning for progeny from a 500 kg dam

$\boxed{ME_m P_w\ 450\ kg\ D}$ - ME_m from birth to weaning for progeny from a 450 kg dam

$\boxed{ME_G\ mg\ p_w}$ - ME for gain of marginal product at weaning

$\boxed{ME\ mg\ p_w}$ - ME for marginal product at weaning (gain plus maintenance)

Figure 4: Method for calculation of ME and associated costs of the marginal product of calf at 1 year of age as associated with size of dam. (ME_m calculated for 24 hours, ME expressed in Mcal).

$$\boxed{\text{Y wt P 500 kg D}} - \boxed{\text{Y wt P 450 kg D}} = \boxed{\text{mg p Y}} \qquad (9)$$

$$\boxed{\text{Y wt}} - \boxed{\text{Wwt}} = \boxed{\text{mg p F}} \qquad (10)$$

$$ME_m \left(\boxed{\text{W wt P}} + \boxed{\frac{\text{GFP}}{2}} \right)^{0.75} = \boxed{ME_m \text{ P F}} \qquad (11)$$

$$\boxed{ME_m \text{ P F, 500 kg D}} - \boxed{ME_m \text{ P F, 450 kg D}} = \boxed{ME_m \text{ mg p F}} \qquad (12)$$

$$(12) + \boxed{ME_G \text{ mg p F}} = \boxed{\text{ME mg p F}} \qquad (13)$$

(13) x (185 days) x (Cost/Mcal ME, finishing ration) = cost of $\boxed{\text{mg p F}}$ (14)

(7) + (14) = Total cost $\boxed{\text{mg p Y}}$ (15)

$$\frac{(15)}{\text{mg p Y kg}} = \text{Cost/kg } \boxed{\text{mg p Y}} \qquad (16)$$

DEFINITIONS OF ABBREVIATIONS:

ME - metabolizable energy

ME_m - metabolizable energy for maintenance/kg $^{0.75}$/24 hours

$\boxed{\text{Y wt P 500 kg D}}$ - Weight of progeny at one year of age from a 500 kg dam

$\boxed{\text{Y wt P 450 kg D}}$ - Weight of progeny at one year of age from a 450 kg dam

$\boxed{\text{mg p Y}}$ - marginal product at one year of age

$\boxed{\text{Y wt}}$ - yearling weight

$\boxed{\text{W wt}}$ - weaning weight

$\boxed{\text{mg p F}}$ - marginal product from weaning to one year of age

$\boxed{\text{W wt P}}$ - weaning weight of progeny

$\boxed{\frac{\text{GFP}}{2}}$ - (gain of progeny from weaning to one year of age ÷ 2

$\boxed{ME_m \text{ P F}}$ - ME_m for progeny from weaning to one year of age

$\boxed{ME_m \text{ mg p F}}$ - ME_m for marginal product from weaning to one year of age

$\boxed{\text{ME mg p F}}$ - ME for marginal product from weaning to one year of age (gain plus maintenance)

Figure 5: Method for calculation of ME and associated costs of the marginal product at weaning as associated with a 1 kg increase in daily milk production of dam. (ME_m calculated for 24 hours, ME expressed in Mcal).

$$\frac{\text{GE milk}}{\text{ME Pasture}} = \text{EFF} \qquad (17)$$

$$\text{GE milk/kg} \times \frac{1}{\text{EFF}} = \text{ME pasture/kg milk} \qquad (18)$$

$$(18) \times (180 \text{ days}) \times (\text{Cost/Mcal ME, pasture}) = \text{Cost}, \qquad (19)$$

$$\frac{(19)}{\boxed{\text{mg p W}}\ \text{kg}} = \text{cost/kg } \boxed{\text{mg p W}} \qquad (20)$$

DEFINITIONS OF ABBREVIATIONS:

EFF - efficiency of utilization of pasture for milk synthesis

GE - gross energy

ME - metabolizable energy

$\boxed{\text{mg p W}}$ - marginal products at weaning

The influence of cow-body size on calf performance

Since body weight varies with condition of animal, it may not be a reliable indicator of physiological size. As indicated in Chapter 5, weight and height of cow together were found to be more reliable in predicting growth response of calf than either variable alone. However, the effect of cow size, regardless of measurement, on calf performance was found to be low and fluctuating. Since ME_m is a function of body weight rather than skeletal size, it becomes extremely difficult to relate skeletal size to an energetic study. As indicated by weight-height ratios, the cows at the University of Alberta ranch were probably below average condition, postcalving. Hence, using body weight as a measure of physiological size would not likely be confounded by the presence of excessively fat cows.

As reported in Chapter 3, a 10 kg increase in postcalving weight of dam, independent of milk yield, resulted in about a 0.7 kg increase in weaning weight of progeny. Using 3 sets of data, a 10 kg increase in postcalving weight of dam resulted in a -0.24, 1.96 and 2.12 kg increase in 365 day weight of male progeny, respectively (Chapter 4).

Extrapolating from the above results, a 50 kg increase in body weight of dam was considered to be associated with a 3.5 kg and 10 kg increase in calf weight at weaning and 1 year of age, respectively.

The influence of milk yield of dam on calf performance

Using 2 sets of data, a 1 kg increase in 24 hour milk yield resulted in an increase of 0.06 and 0.07 kg in average daily gain to weaning of progeny or an 11 and 14 kg increase in weaning weight, respectively (Chapter 3). The fat content of milk was reported to

range from 4.10 to 4.66% in August. Since milk ejection was stimulated by oxytocin which removes the residual milk reported to be high in fat content (Wherlock and Dodd, 1969), the fat percentages as reported in this study were probably higher than that received by the suckling calf.

Therefore, a 1 kg increase in 24-hour-milk yield containing 4% fat was considered to increase weaning weight of calf by 12 kilograms.

Energy requirements for maintenance of beef cows

The energy requirement for maintenance per unit body weight of beef cattle is subject to considerable variation (Tables 34 and 35). Before deciding on a value for estimating the maintenance requirement of energy for beef cattle some clarification as to why such variation occurs is in order.

Under farm conditions, the ME_m for beef cattle can vary considerably as a result of differences in activity and environmental temperature (Young and Berg, 1970; Webster, 1967). There are indications that dairy breeds may have a higher fasting metabolism than beef breeds. Blaxter and Wainman (1966) reported values for fasting metabolisms for Ayrshire and beef type steers as 90.7 and 72.4 kcal/ $W^{0.75}$, respectively. The fasting metabolism of pregnant cows may increase by 20% in the latter stages of pregnancy (Cuthbertson, 1969). Lactating cows may have a higher fasting metabolism than non-lactating cows (Flatt et al., 1967a, b; Neville and McCullough, 1969), however, this observation was not supported by Van Es and Nijkamp (1967). It is well established that young animals have a considerably higher fasting metabolism than older animals (Blaxter, 1967; Ritzman and

Colovos, 1943; Gonzalez-Jimenez and Blaxter, 1962).

Estimates as reported in the literature for ME_m of cows ranged from 104 to 175 kcal/kg $W^{0.75}$ (Table 34). Young and Berg (1970) estimated that ME_m of beef cows increased by as much as 30% when the animals were subjected to cold stress (below 0° to 5°F). Webster (1967) indicated that ME_m of beef cows increased by as much as 48% when grazing on free range as compared to housed animals. Young and Dietz (1971) estimated ME_m of beef cows in varying body condition to range from 137 to 146 kcal/kg$^{0.75}$/24 hours. These workers reported the cows to be in semi-confinement, without shelter or bedding during winter. Thus the choice of a single value is an arbitrary decision guided by a priori knowledge of conditions under which the animals exist.

On the basis of these studies, the energy requirements for maintaining beef cows may not vary appreciably between summer and winter. The additional requirement of cold stress during winter confinement may approximately balance with the additional activity requirement while grazing on range in the summer. The value of ME_m for beef cows was chosen as 150 kcal/kg $W^{0.75}$/24 hours.

Energy requirements for maintenance of beef calves

Although fasting metabolism of young calves is generally accepted as being higher than for older animals, it does not necessarily follow that ME_m would be proportionately higher. Milk being a readily available highly digestible food, the suckling calf has a relatively low energy requirement for eating. Frequently on range, calves will be found at rest while their dams are actively grazing. Table 35 shows estimated values of ME_m for cattle 1 month to 48 months of age

(derived from fasting metabolism values, ARC, 1965). Webster et al. (1967) reported fasting metabolism as 141 kcal/kg $W^{0.75}$/24 hours for 6 month old calves, which is somewhat higher than the value reported by ARC (1965). Blaxter (1962) indicated that the energy requirement for activity of a calf in a box stall to be about 10% of fasting metabolism. Assuming the energy requirement of activity for a suckling calf on range to require 20% more than the ME for fasting metabolism, the ME_m would approximate 180 kcal/kg $W^{0.75}$/24 hours (Table 35).

The ME_m of a postweaning calf in feedlot is more predictable than for either a beef cow or suckling calf. Feedlot cattle receiving a high energy ration ad libitum are inclined to be inactive and because of a high heat output, they have a low critical temperature. Hence, the ME_m of feedlot cattle would approach fasting metabolism with perhaps an upward adjustment of 10 to 15% for activity expenditure. Lofgreen and Garrett (1968) estimated the net energy for maintenance (NE) of steers to range from 72 to 82 kcal/kg $W^{0.75}$/24 hours with a mean value of 77 kcal, which is the value adopted by NRC (1970). Adjusting this value upwards by 15% for activity would give a NE_m of 89 kcal/kg $W^{0.75}$/24 hours. Assuming a finishing ration to contain 2.8 Mcal of ME/kg dry matter, the efficiency of utilization of ME for maintenance would approximate 74% (ARC, 1965). Based on these assumptions, the maintenance requirement of metabolizable energy for beef cattle in feedlot would be about 120 kcal/kg $W^{0.75}$/24 hours.

<u>Metabolizable energy requirement for growth of a suckling calf</u>

Energy expenditure above maintenance for growth is largely a

TABLE 34: Estimates of energy requirements for maintenance (ME_m) for mature cows

Reference		Cow description	kcal ME_m/kg $W^{0.75}$ + (24 hours)
Flatt et al.	(1967a)	dairy lactating	144.7
Es and Nijkamp	(1967)	dairy lactating	107.3*
Owen and Nielsen	(1968)	dairy lactating	123.6*
Garrett et al.	(1959)	beef lactating	112.0
Neville and McCullough	(1969)	beef lactating	178.4
Flatt et al.	(1967b)	dairy non-lactating	110.0
Es and Nijkamp	(1967)	dairy non-lactating	107.0*
Neville and McCullough	(1969)	beef non-lactating	137.4
Young and Berg	(1970)	beef non-lactating	
		a) above critical temperature	123.0*
		b) below critical temperature	167.0*
Webster	(1969)	beef	
		a) housed	104.0*
		b) free range above critical temp.	153.0*
		c) free range below critical temp.	175.0*
NRC	(1970)	beef non-lactating	128.0*

+ kilocalories of metabolizable energy for maintenance per kilogram of body weight to the 0.75 power.
* derived from author's values which were reported in terms other than kcal ME_m/kg $W^{0.75}$/24 hours.

TABLE 35: Estimated mean values for the fasting heat production of cattle

Age (months)	Fasting[+] metabolism (NE) (kcal/kg $W^{0.73}$)	Assumed weight (kg)	Fasting[‡] metabolism (NE) (kcal/kg $W^{0.75}$)	Assumed diet	NE/ME[ϕ]	ME-fasting metabolism (kcal/kg $W^{0.75}$)[θ]
1	140	50	132	milk	.85	155
3	135	100	123	½ milk	.80	154
6	125	200	113	¼ milk	.75	150
12	110	400	98	forage	.70	140
18	100	450	88	forage	.70	126
24	95	450	85	forage	.70	121
36	90	450	79	forage	.70	113
48	85	500	74	forage	.70	105
$>$48	80	500	70	forage	.70	100

\+ ARC (1965).
‡ derived from column 2 and column 3.
θ derived from column 4 and column 6.
ϕ Assuming the efficiency of utilization of metabolizable energy of milk for maintenance to be 85% (Blaxter, 1952; Stobo, 1964) and for forage containing 2.2 Mcal/kg dry matter to be 70% (ARC, 1965).

function of tissue composition and efficiency of utilization of metabolizable energy. The calorific value of tissue increases with fat content, hence as the proportion of fat increases, the net energy requirement per unit of tissue deposition increases. As animals become older they tend to deposit a higher proportion of net energy gain as fat. A second factor of importance in determining the feed requirement per unit gain is the efficiency of utilization of ME for net tissue synthesis. Generally the higher the energy content per unit dry matter of feed the greater will be the efficiency with which ME is utilized for growth.

Conversions for digestible energy of milk have been reported as 307, 268 and 302 kcal for synthesis of 100 grams of live weight gain in young calves (Blaxter and Wood, 1951; Brisson et al., 1957; Roy et al., 1964) which is in general agreement with the value listed in Table 36 for a 100 kg calf. A calf increasing in weight from 100 to 200 kg on a predominantly milk diet would require about 3.7 Mcal of ME per kg gain in body weight (Table 36). Since the suckling beef calf is sustained on a predominantly milk diet synthesized by its dam through pasture, it is necessary for purposes of estimating cost of gain and maintenance of calf to convert the ME received by the calf through milk to ME of pasture required to synthesize the milk. A ration of good quality roughage (pasture) would be expected to contain about 2.2 Mcal of ME per kg dry matter which would be utilized at about 68% efficiency for milk synthesis (ARC, 1965).

Metabolizable energy as a percent of gross energy of milk has been estimated as 95.1, 95 and 94.5 (Gonzalez-Jimenez and Blaxter, 1962; Blaxter, 1952; Walker and Jagusch, 1969). Hence, ME of milk

multiplied by 1.55 would be equal to the ME of pasture required to synthesize the milk (100/95 x 100/68 = 1.55). Therefore, 5.74 Mcal of ME (3.7 x 1.55) from pasture would be required for the synthesis of 1 kg of calf gain indirectly through milk.

Metabolizable energy requirement for growth of a calf in feedlot

A calf increasing in weight from 200 to 400 kg on a predominantly grain ration would require about 7.3 Mcal of ME per kg of tissue deposition (Table 36). This calculation is based on a net energy retention of 4 Mcal per kilogram gain and an efficiency of utilization of ME for growth or fattening of 55% (ARC, 1965).

The metabolizable energy requirement for milk synthesis

The calorific value of milk containing 4% fat is 750 kcal per kilogram (ARC, 1965). Assuming that the ME of pasture consumed above maintenance is utilized at 68% efficiency for milk synthesis, 1.1 Mcal of ME from pasture would be required for the synthesis of 1 kg of milk.

Estimates of associated costs

Pasture containing 2.2 Mcal of ME per kg of dry matter valued at 1.1¢ per kg ($10.00 per ton dry matter) would equal 0.5¢ per megacalorie.

Hay containing 2.2 Mcal of ME per kg of dry matter valued at 2.2¢ per kg ($20.00 per ton dry matter) would equal 1.0¢ per megacalorie.

Predominantly concentrate containing 2.8 Mcal of ME per kg of dry matter valued at 4.4¢ per kg ($40.00 per ton dry matter) would equal 1.57¢ per megacalorie.

For purpose of the marginal analysis, the required parameters as derived from values reported in previous chapters and literature

TABLE 36: Energy retention per kg of live weight gain for cattle at various weights and rates of gain[+]

Live weight of animal (kg)	Daily gain (kg)	Energy retention per kg gain (NE) (Mcal)	NE_p/ME[ð] (%)	Estimated ME/kg gain (Mcal)
100	0.88	2.3	80 (a)	2.8
200	0.90	2.8	60 (b)	4.6
200	1.37	3.3	55 (c)	6.0
300	1.38	4.0	55	7.3
400	1.38	4.7	55	8.6

\+ ARC, (1965).

ð NE_p/ME – (a) predominantly milk,
(b) milk and forage,
(c) oats, barley and limited hay – assumed 2.8 Mcal/kg dry matter.

review are summarized as follows:

1. A 50 kg increase in cow-body weight results in a 3.5 and 10 kg increase in weight of calf at 180 (weaning) and 365 days of age, respectively. This assumes that the calves over the postweaning period receive a predominantly concentrate ration ad libitum.
2. A 1 kg increase in 24-hour-milk yield (4% fat) of dam results in a 12 kg increase in weight of calf at 180 days of age.
3. The ME_m of a beef cow = 0.15 Mcal/kg $W^{0.75}$/24 hours.
4. The ME_m of a beef calf to weaning = 0.18 Mcal/kg $W^{0.75}$/24 hours.
5. The ME_m of a beef calf on full feed postweaning = 0.12 Mcal/kg $W^{0.75}$/24 hours.
6. The ME_G of a beef calf to weaning = 5.74 Mcal of ME from pasture through milk/kg gain.
7. The ME_G of a beef calf postweaning on full feed of a predominantly concentrate ration = 7.3 Mcal/kg gain.
8. Synthesis of 1 kg of 4% milk (750 kcal) requires 1.1 Mcal, ME of pasture.
9. The ME of milk x 1.55 = ME of pasture required to synthesize the milk.
10. Milk production and cow-body size are independent of each other.
11. Costs:

    Pasture - 0.5¢/Mcal ME

    Hay - 1.0¢/Mcal ME

    Predominantly Concentrate - 1.57¢/Mcal ME

C. RESULTS AND DISCUSSION

The results of the marginal analysis for preweaning and postweaning calf performance as associated with body weight of dam are given in Table 37. These results were calculated from the parameters described above in accordance with the models presented in Figures 3 and 4.

The energy input required to produce the 3.5 kg marginal product of progeny at weaning as associated with a 50 kg increase in weight of dam included:

a) The ME_m of the additional 50 kg of dam for 365 days which was estimated as 438 Mcal of ME of which 216 was from pasture and 222 was from hay,

b) The ME_m and ME_G for the marginal product of calf at weaning was estimated as 40 Mcal of ME from pasture.

Valuing the ME according to source resulted in an estimated total cost of $3.50 which would be $1.00 per kilogram (45¢ per lb) of marginal product at weaning. Based on the above values and assumptions, the marginal analysis suggests that if calves were to be sold at weaning at current prices, the value of marginal product as associated with cow size would not be sufficient to offset the additional feed costs.

Comparing a 500 kg cow with a 450 kg cow, the expected marginal product of progeny at one year of age was 10 kg, 6.5 kg of which were realized during the postweaning period. The ME_m and ME_G of calf from weaning to one year of age was estimated as 75 megacalories. The estimated costs for preweaning and postweaning marginal product

TABLE 37: A marginal analysis for a 450 and 500 kg beef cow

	Kind of feed	Metabolizable energy (ME) required: Maintenance+ (Mcal)	Growth‡ (Mcal)	Cost per Mcal ME (¢)	Total cost ($)
Cow - 500 kg	180 days pasture	2855			
Cow - 450 kg	180 days pasture	2639			
Difference		216		0.5	1.08
Cow - 500 kg	185 days hay	2934			
Cow - 450 kg	185 days hay	2712			
Difference		222		1.0	2.22
Marginal product - weaning (3.5 kg)	180 days milk	13	13		
	pasture converted to milk⌀	20	20	0.5	.20
Total cost of marginal product (weaning)					3.50
Marginal product - postweaning (6.5 kg)	Finishing ration	27	48	1.57	1.18
Total cost of marginal product (1 year)					4.68

* Metabolizable energy (Mcal) per kg of dry matter assumed to be 2.2 for pasture and hay and 2.8 for the finishing ration which consisted of predominantly grain (oats and barley).

\+ Daily maintenance requirement (Mcal of ME) was calculated by multiplying kg $W^{0.75}$ by 0.15, 0.18 and 0.12 for cows, calves to weaning and calves postweaning, respectively.

‡ The ME requirement for growth (Mcal) was calculated by multiplying gain in weight by 3.7 and 7.3 respectively for calves to weaning and calves postweaning.

⌀ For calves to weaning the ration was assumed to be predominantly milk containing 4% fat derived from pasture through the dam.

equaled \$4.68 or \$0.47 (21¢ per lb) per kg marginal product of progeny at one year of age. The marginal analysis suggests that if calves were fed ad libitum on a predominantly concentrate ration during the postweaning period to one year of age, in terms of value of marginal product as related to additional feed costs, the larger cow would have an economic advantage.

It is recognized that the marginal analytical procedure does not take into account all factors related to efficiency of a cow-calf enterprise. The cost of raising the larger cow to maturity would be somewhat higher, although this would be partly offset by higher salvage value. Fixed costs as related to cow size would vary depending on market value, number of cows maintained to yield an equal amount of beef, breeding fees and so on. Any differences related to age of puberty, fertility, ease of calving, survival and longevity would all have important implications. Kress et al. (1969) with calf-weaning ages of 240 days, reported that efficiency had a small negative relationship with cow weight, a positive relationship with wither height of cow and a negative relationship with weight-height ratio of cow which reflects condition. They concluded "that skeletally large and small cows were approximately equal in efficiency, with a large cow having a slight advantage and that fat cows were inefficient". The inefficiency of fat cows was also reported by Young and Dietz (1971). Thomas and Melton (1969) in a preliminary study found little difference in beef production efficiencies due to cow size difference. They reported that Charolais calves gained more rapidly than Hereford calves, but that the extra gain was offset by higher maintenance costs. They found calves from large and small Hereford cows to have similar

gains to 210 and 365 days of age.

Feed costs of the dam represent a fixed overhead chargeable to the calf which diminishes per unit body weight of calf as the calf becomes larger. The marginal analysis points out the importance of crediting the larger cow with the net efficiencies of marginal product as associated with cow size over the postweaning period. However, for the present study a slaughter age of one year was assumed. For a more meaningful comparison of cow size, slaughtering at optimum carcass composition rather than some predetermined age or weight would undoubtedly provide a more realistic base for assessment. The age and weight at which an animal reaches a given stage of maturity tends to increase with mature size (Joandet and Cartwright, 1969; Cartwright, 1970). Hence, calves from larger cows vs. calves from smaller cows could be slaughtered at heavier weights but with similar carcass composition which would tend to reduce the fixed overhead of maintaining the larger cow. However, calves carried to heavier weights in feedlot have higher maintenance requirements which tends to reduce gross feed efficiency. Perhaps, given a set of feed costs and cattle prices, optimum size of cow could be assessed by a study of these opposing relationships.

The marginal analysis of growth rate of calf as associated with milk yield of dam essentially involves the net efficiency of utilization of milk energy for tissue synthesis with exception of maintenance requirement for marginal gain of calf as associated with the additional milk. A relatively high efficiency would be expected by increasing food intake for production. Indeed, the net utilization of metabolizable energy of milk above maintenance has been reported as 71, 77, 82

and 84.5% (Walker and Jagusch, 1969; Gonzalez-Jimenez and Blaxter, 1962; Blaxter, 1952).

As reported in Chapter 3 a 1 kg increase in 24-hour-milk yield was associated with about a 12 kg increase in calf weight at 180 days. Assuming the milk to contain 0.75 Mcal of gross energy per kg and that ME of pasture is utilized at 68% efficiency for the net synthesis of milk, then 1.1 Mcal of ME of pasture would be required above maintenance to synthesize 1 kg of milk. Valuing pasture at 0.5¢ per Mcal of ME, the cost per kg of calf weaned as associated with increased milk production through pasture would be 8.25¢ (1.1 x 180 days x 0.5¢ x$\frac{1}{12}$).

At stated feed costs and prevailing cattle prices, increasing milk production of beef cows would be highly profitable. In the interest of increasing net return of a cow-calf enterprise, under conditions of adequate nutrition, milk yield would warrant high priority as a trait to be considered in a beef breeding program.

GENERAL SUMMARY AND CONCLUSIONS

The objectives of this study were to examine the separate and joint effects of several cow-calf variables with particular reference to milk yield and size of dam on calf performance. Since milk yield and size of dam influence feed input and hence costs, these variables as associated with calf performance were also studied by means of a marginal economical analysis.

The data were obtained from the University of Alberta beef breeding herd located at the University ranch, Kinsella, Alberta. Data for the years 1966-70, with one exception, were analyzed on a within-year basis, thus providing an indication of repeatability for calculated parameters.

The breeding composition of the herd was complex with considerable variation between years in herd composition. The cow herd consisted mainly of Hereford, Angus, Galloway and hybrid breeding. The hybrids were a synthetic of Charolais, Angus and Galloway breeding. Breeds of sires used were Hereford, hybrid, Charolais, Brown Swiss and Shorthorn. To obtain meaningful sub-class numbers, animals were categorized by breed groups rather than specific breed combinations. For example, breed of sire differences were estimated across breed of dam categories and conversely breed of dam differences were estimated across breed of sire categories.

Preweaning performance of calf was examined across sex, however, male and female calves were fed differently over the postweaning period which required sub-classifying the data by sex for the purpose of studying calf performance to 365 days of age. Variables considered

in the study were milk yield, age, body weight change over winter and summer, and body weight and body measurements of dam; breed of sire and dam; weaning age, sex and age of calf.

The data were analyzed by stepwise-multiple regression using a general linear model where percent additional variance explained by each independent variable is conditional to the other independent variables preceding it in the equation. By holding certain independent variables constant, as determined by a priori reasoning, the direct association of an independent variable of interest with a dependent variable was determined.

Milk yield

Twenty-four hour milk yield was determined for the cow herd in August and October, 1966 and 1967. Milk ejection was stimulated by oxytocin. Variables studied within year were August and October 24-hour-milk yield, total protein, total energy, total solids and percentages of fat, solids-not-fat and protein. The effect of the 7 variables on preweaning performance of calf were considered singly and in combination. For 1966 data, little additional variation in average daily gain (ADG) of calf to weaning was explained by the inclusion of other milk variables over that explained by milk yield alone. For 1967, the inclusion of milk-percent components accounted for 2 to 7% of total variance in ADG to weaning over that explained by milk yield alone. The average of two milkings was more consistent in explaining variance of calf performance than a single milking. The relationship of milk yield to calf performance was essentially linear. It was concluded that average milk yield for the two milkings was a suitable parameter

for studying the association of milk with calf performance.

The joint and separate effects of several cow-calf variables on milk yield were studied. Independent variables considered were: breed, postcalving weight, winter-weight losses, summer-weight gain and age of dam; weaning age, sex and birthweight of calf. Total variance of milk yield explained by all variables together was only 40 and 52%, respectively for 1966 and 1967 data. Breed of dam accounted for 17.9 and 32.8% and age of dam accounted for 15.3 and 12.6% of total variance in milk yield, for the two years. Breed and age of dam together accounted for 82 and 87% of explained variance in milk yield.

Cow-body weight, independent of age may have some influence on milk yield. Cow weight with age held constant explained 0.0 and 8.0% and cow age with weight held constant explained 7.7 and 6.6% of additional variance in milk yield, respectively for 1966 and 1967. Winter-weight loss of cow did not influence milk yield. Cows with lesser weight gain over summer tended to yield more milk. The effect of sex of calf on milk yield was inconsistent. Cows suckling male calves yielded more milk than cows suckling female calves in 1966 but less in 1967. Birth weight of calf had a small positive influence on milk yield. Association between milk yield of dam and preweaning performance of progeny was high.

It was concluded that the quickest way to improve milk yield would be by introduction of breeds with high milk yield potential and by indirect selection through the selection of breeding animals with high preweaning performance.

Of all variables considered, milk yield had the greatest influence on preweaning performance. With sex and age of calf held constant,

milk yield explained 56 to 59% of the variation in ADG to weaning and 42 to 57% of the variation in weaning weight. Holding sex and age of calf, age of dam and breed of sire and dam constant milk yield still explained about 20% of total variance in preweaning performance of calf which suggests considerable variation in milk production between cows of similar age and breed. A 1 kg increase in daily milk yield was associated with a 0.064 to 0.079 kg increase in ADG of calf to weaning and an 11.3 to 14.6 kg increase in weaning weight.

Breed effect

The hybrid, Angus and Galloway dams were similar for milk yield and excelled Herefords by 1.20 to 1.50 kg per 24 hours. Subject to the more restricted grazing conditions of 1967, Hereford dams tended to retain body condition at expense of milk yield and associated calf gain whereas the other breed groups tended to produce milk at the expense of body weight. There was little breed difference in percentage-milk components. Birth weights were not significantly different between breed of dam categories. The Angus, Galloway and hybrid dams were similar in respect to ADG of progeny to weaning and their value excelled calves from Hereford dams by about 25 kg at weaning. Breed of dam explained about 23% of the variation in ADG of calf to weaning most of which was attributable to differences in milk yield.

Breed of sire explained only 1.4 to 5.7% of the variance in ADG of calf to weaning. Calves from Brown Swiss, Charolais and hybrid sires excelled Hereford-sired calves in preweaning performance. Hereford-sired calves excelled Shorthorn-sired calves in ADG to weaning.

Breed of sire and dam differences explained from 12 to 14% of variance in postweaning average daily gain for male calves for the first 2 years of data. However, for 1968-70 data, where Hereford and hybrid breeding were included, breed differences explained only 1% of the variance in postweaning performance of progeny. Hybrid male calves had slightly higher postweaning gains than Hereford male calves. This trend was reversed for female calves which were fed a restricted postweaning ration. There was a tendency for heavier vs. lighter hybrid female calves at weaning to have slightly lower postweaning gains. This may have been attributable to a higher feed requirement for maintenance.

Birth weight

Average birth weights of calves ranged from 33 to 35.6 kg between years. Calves heavier at birth tended to grow more rapidly over both the preweaning and postweaning period. Subject to the conditions of the equations, birth weight accounted for 8.8 and 4.7% of the variance in weaning weight respectively for 1966 and 1967 data. When calves were separated by sex, birth weight appeared to be more highly associated with preweaning performance of female calves. This pattern was consistent between years. For male calves a 1 kg increase in birth weight was associated with a 1.47 to 1.68 kg and a 2.89 to 4.14 kg increase in calf weight at 180 and 365 days, respectively. For female calves a 1 kg increase in birth weight resulted in a 1.77 to 2.78 kg and a 2.86 to 4.42 kg increase in calf weight at 180 and 365 days of age, respectively. Because of the restricted ration, response of growth to birth weight in the postweaning period was lower for female

calves than for male calves. This tended to offset the higher preweaning response of female calves and the two sexes averaged about the same at 365 days of age. Although there appears to be a positive relationship between birth weight of calf and growth rate, deliberate selection for heavier birth weight may be a questionable procedure in respect to the possibility of increasing calving difficulties. Experience gained from the University of Alberta beef breeding herd suggests that considerable progress can be realized in respect to increasing calf performance without necessarily increasing birth weights. Birth weights between the hybrid and Hereford lines were similar, however calf performance from the hybrid line consistently excelled that of the Hereford line.

Sex and age of calf

For 1966 and 1967 data, male calves excelled female calves by 2 kg for birth weight, by 0.03 kg for ADG to weaning and by 8 to 9 kg in weaning weight.

The association of calf age with ADG to weaning was small, accounting for only 0.5 to 2.1% of the variance. However, as expected, calf age had a considerable influence on weaning weight and accounted for 38.2 and 6.1% of the variance, respectively for 1966 and 1967. The regression coefficient for ADG to weaning on calf age was negative for 1967, which accounted in part for the lower percentage of variance in weaning weight explained by calf age for that year. Average daily gain of calves to weaning was also higher for 1966.

Size of dam

The mean postcalving weights of cows by breed across age were

relatively similar, approximating 400 kilograms. The postcalving weights of Hereford dams were slightly greater than the other breed groups. However, with exception of 1967, the other breed groups realized greater summer-weight gains which tended to equalize body weight differences at weaning time. In the fall of 1969, weights and body measurements of the cow herd were taken. Breed of dam differences within age of dam sub-classes were not large for body weight, length and heart girth. However the hybrid and non-British breed crosses (HYC) excelled the Herefords and British breed crosses (HEAG) by about 5 cm in height measurements.

The influence of cow-body weight on preweaning performance of calf was low, accounting for only 0.6 to 1.5% of total variance. Across sex of calf and breed of dam, a 10 kg increase in postcalving weight of dam resulted in a 0.7 kg increase in weaning weight of calf. The results are conditional to the equations and are relatively consistent between years.

Within breeds, preweaning performance of calves responded more to cow height than body weight for HEAG dams and about equal to height and weight for HYC dams. The weight/height ratio was higher for HEAG dams than HYC dams indicating that the HEAG cows were in better condition. This may explain the breed difference in response of calf performance to body weight of dam. Height and weight of cow together were considered to be more consistent in predicting response of calf performance to cow size than either variable alone.

Response of postweaning performance of male calves to cow-body weight was greater than for preweaning performance. This was possibly attributable to the postweaning environment where calves were fed ad

libitum and could therefore fulfil their growth potential. With exception of 1966-67 when response of calf performance to cow-body weight was negative, a 10 kg increase in cow weight was associated with about a 2.0 kg increase in calf weight at 365 days of age.

Influence of preweaning on postweaning performance

Male calves with higher ADG to weaning tended to have a slightly higher postweaning average daily gain. A 10 kg advantage in weaning weight for male calves resulted in a 12 to 14 kg advantage in weight at 365 days of age. Because of the restricted ration and slower growth rate, response of postweaning average daily gain to average daily gain to weaning for female calves was somewhat lower than for male calves.

Economic interpretation

A marginal analysis based on current feed costs and cattle prices suggested that the additional weight of calf weaned as associated with larger cow size would not have sufficient value to offset the higher feed costs associated with maintaining the larger cow. However, by crediting the larger cow with the net efficiencies of associated post-weaning gain of progeny, the larger cow would have an economic advantage.

Additional weaning weight as associated with increased milk yield of dam was found to be highly profitable.

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